CONTRACT REPORT NO. 0SQ81-00146

EVALUATION OF THE EFFECT OF CATALYST TYPES, ENGINES AND LOAD CYCLES ON THE MUTAGENIC ACTIVITY OF DIESEL EXHAUST EXTRACTS

for

CANMET,
Department of Energy Mines & Resources
Energy Research Labs,
555 Booth Street
Ottawa, Ontario K1A 0G1

DSS File No.:23SQ.23440-1-9068
DSS Serial No.:
ORF Contract No.: 48-30285

by

A.J. Horton
N.S. Belson
D.K. Smith
A. Lawson
H. Vergeer

March 25th, 1985

ONTARIO RESEARCH FOUNDATION
Environmental & Chemical Engineering Division

ONTARIORESEARCH
FOUNDATION

SHERIDAN PARK RESEARCH COMMUNITY
MISSISSAUGA, ONTARIO, CANADA L5K 1B3 • (416) 822-4111 • TELEX 06-982311

142 pp

MAY 03 1986
MICROMEDIA

WE, THE ONTARIO RESEARCH FOUNDATION, STIPULATE THAT THIS DOCUMENT IS SUBJECT TO THE FOLLOWING TERMS AND CONDITIONS:

1. ANY PROPOSAL CONTAINED HEREIN WAS PREPARED FOR THE CONSIDERATION OF THE ADDRESSEE ONLY. ITS CONTENTS MAY NOT BE USED BY NOR DISCLOSED TO ANY OTHER PARTY WITHOUT OUR PRIOR WRITTEN CONSENT.
2. ANY TESTING, INSPECTION OR INVESTIGATION PERFORMED BY US WILL BE CONDUCTED IN ACCORDANCE WITH NORMAL PROFESSIONAL STANDARDS. NEITHER WE NOR OUR EMPLOYEES SHALL BE RESPONSIBLE FOR ANY LOSS OR DAMAGE RESULTING DIRECTLY OR INDIRECTLY FROM ANY DEFAULT, ERROR OR OMISSION.
3. ANY REPORT, PROPOSAL OR QUOTATION PREPARED BY US REFERS ONLY TO THE PARTICULAR MATERIAL, INSTRUMENT OR OTHER SUBJECT REFERRED TO IN IT. NO REPRESENTATION IS MADE THAT SIMILAR ARTICLES WILL BE OF LIKE QUALITY.
4. NO REPORT ISSUED BY US SHALL BE PUBLISHED IN WHOLE OR IN PART WITHOUT OUR PRIOR WRITTEN CONSENT.
5. OUR NAME SHALL NOT BE USED IN ANY WAY IN CONNECTION WITH THE SALE, OFFER OR ADVERTISEMENT OF ANY ARTICLE, PROCESS OR SERVICE.
6. WE RESERVE THE RIGHT NOT TO COMMENCE AND/OR CONTINUE ANY WORK UNTIL PAYMENT ARRANGEMENTS SATISFACTORY TO US ARE ESTABLISHED.

EVALUATION OF THE EFFECT OF CATALYST TYPES, ENGINES AND LOAD CYCLES ON THE MUTAGENIC ACTIVITY OF DIESEL EXHAUST EXTRACTS

TABLE OF CONTENTS

PAGE

1. INTRODUCTION 3
2. OBJECTIVES 4
3. DIESEL ENGINES TESTED (ORF) 5
4. DYNAMOMETER SAMPLES (ORF) 6
   4.1 Dilution Ratio 7
5. SAMPLE COLLECTION AT LOCATIONS OTHER THAN ORF 7
   5.1 Hi Volume Samples 7
   5.2 Underground Samples 8
   5.3 CANMET Samples, Ottawa 9
6. SAMPLE CHARACTERISTICS 10
   6.1 Sampling Artifacts 10
   6.2 Handling and Storage 11
   6.3 Extraction 12
   6.4 Concentration and Preparation of Extracts 13
   6.4 Amount of Whole Diesel Particulates Extract Required for Mutagenicity Testing 13
7. MUTAGENICITY TESTING 14
   7.1 Theory (How the Assay System Detects Mutagenic Materials) 15
   7.2 Genetic Activity 15
   7.3 Base-Pair Substitution Mutations 16
   7.4 Frameshift Mutations 16
   7.5 Metabolic Activation 16
   7.6 Mutagenic Potency (Pure Compounds) 17
   7.7 Positive Mutagen 17
   7.8 Toxicity 18
   7.9 Net Revertants (Revertants/Plate) 18
   7.10 Specific Activity (Revertants/Microgram) 18
   7.11 Total Activity (Revertants/Mass) 19
   7.12 Mutagen Density (Revertants/Cubic Metre) 19
   7.13 Total Mutagenicity (Revertants/M^3 Raw Exhaust) ... 19
   7.14 The Salmonella Tester Strains 20
   7.15 Tester Strains Employed in Routine Mutagenicity Testing 21
8. RESULTS AND DISCUSSION 24
   8.1 Dilution Ratio Selection and Approval (Task 1A) .. 24
   8.2 Raw (non-treated) Whole Diesel Exhaust 26
   8.2.1 Deutz F6L-714 Diesel Engine 26
   8.2.2 Deutz F6L 912W Diesel Engine 28
   8.2.3 Caterpillar 3304 Diesel Engine 28
   8.2.4 Detroit DDAD 8V71N Diesel Engine 29

TABLE OF CONTENTS (Con't)

PAGE

8.2.5 Deutz F6L 714 Diesel Engine at 1600 rpm, Full Load 30
8.2.6 Deutz F6L 912W Diesel Engine Operated at CANMET under the INCO Load/Haul/Dump Cycle 31
8.2.7 Deutz F8L 714 Diesel Engine Tested by Laurentian University Underground (mine not in production)... 31
8.3 Catalyst Treated Whole Diesel Exhaust 32
8.3.1 Deutz F6L 714 Diesel Engine and PTX Catalyst at 7/8 Load and 2200 rpm 32
8.3.2 Deutz F6L 714 Diesel Engine and PTX Catalyst at 7/8 Load, 2200 rpm and 1/5th Sampling Time per Filter 33
8.3.3 Deutz F6L 714 Diesel Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm 34
8.3.4 Deutz F6L 714 Diesel Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Not Heated. Storage Effect Examined 35
8.3.5 Deutz F6L Diesel Engine and Johnson Matthey Catalyst at 7/8 Load, 2200 rpm 35
8.3.6 Evaluation of a Johnson Matthey Exhaust Purifier for Particulate and Gaseous Emission 36
9. CONCLUSIONS 38
10. RECOMMENDATIONS 41

REFERENCES 42
APPENDIX I - TABLES 45

EVALUATION OF THE EFFECT OF CATALYST TYPES, ENGINES AND LOAD CYCLES ON THE MUTAGENIC ACTIVITY OF DIESEL EXHAUST EXTRACTS

1. INTRODUCTION

The discovery of mutagenic, and by implication, carcinogenic activity of diesel exhaust particulates has caused serious concern for the underground mining industry. This has led to a requirement to identify the magnitude of this potential health hazard, and to assess possible control techniques to reduce the mutagenic activity.

It is estimated that over 90% of Canadian mines, and 60% of U.S. mines, employ diesels with catalytic converters as exhaust treatment devices. Catalysts are recognized to effectively oxidize carbon monoxide and light hydrocarbons such as methane to carbon dioxide, but they also create the opportunity for oxidizing sulphur dioxide to sulphuric acid.

The sulphuric acid production is a factor against the use of catalysts on underground diesel powered equipment. Continued use of catalysts in this regard would, however, be highly desirable if it was found that the catalyst was capable of oxidizing hydrocarbon material to the extent that it reduced mutagenic activity.

This report presents the results of mutagenic testing of whole diesel exhaust emissions conducted by the Ontario Research Foundation (ORF) for the Canadian Centre for Mineral and Energy Technology (CANMET) of Energy Mines and Resources Canada.

The assessment of the biological activity of diesel particulate extracts using the Ames Salmonella Mutagenicity Assay has been under study in a number of laboratories. Programme studies carried out at ORF (1) and Laurentian University (2)(3) fiscal year 1980/1981 and 1981/1982 addressed the problem of mutagenicity testing of underground diesel exhaust emissions samples. Methodology was developed, which allowed a comparison of the mutagenic activity of whole diesel exhaust particulates emissions collected both from engine dynamometer laboratory tests and samples of diesel exhaust collected from the underground mine atmosphere.

The methods developed to evaluate the mutagenic activity of diesel exhaust emissions showed good correlation between laboratory test data and the underground mine environment samples. Further refinements of methods and testing of samples were conducted to validate the methods and determine the reproducibility of the engine test data. Investigations were conducted to determine if inconsistencies in underground sample data collected in the initial sample programme were due to contamination by other operations taking place in the mine during the sampling period.

The testing was continued to provide the methodology and background information necessary to improve assessment and selection of different heavy-duty diesel engine and exhaust treatment strategies for the underground mining industry.

2. OBJECTIVES

(i) To collect samples of whole diesel exhaust particulates using a dilution ratio of 16 to 1 and the ORF stainless steel dilution tube sampling system for Ames *Salmonella* mutagenicity testing.

(ii) To determine the mutagenic activity using *Salmonella* tester strain TA98 without metabolic activation in the plate incorporation assay for:

(a) Deutz F6L 714 diesel engine operating at 7/8 load, 2200 rpm.
(b) Deutz F6L 912W diesel engine operating at 7/8 load, 2200 rpm.
(c) Caterpillar 3304 diesel engine operating at 7/8 load, 2200 rpm.
(d) Detroit DDAD 8V71N diesel engine operating at 7/8 load, 2200 rpm.
(e) Deutz F6L 714 engine operated at full load, 1600 rpm.
(f) Deutz F6L 912W engine operated at CANMET under the Inco LHD cycle.
(g) Deutz 8L 714 engine sampling supervised by Laurentian University, underground, mine not in production.
(h) Deutz F6L 714 diesel engine and PTX catalyst operated at 7/8 load, 2200 rpm.

(i) Deutz F6L 714 diesel engine and PTX catalyst operated at 7/8 load, 2200 rpm, sampled so that each filter received one fifth the normal exposure to the exhaust gases.

(j) Deutz F6L 714 diesel engine and Dieseler III pelletted type exhaust purifier operated at 7/8 load, 2200 rpm.

(k) Deutz F6L 714 diesel engine and Dieseler III as in (j), with each sampling interval of 1/2 hour separated by 1/2 hour at rated speed and 1/2 load during which time no samples were collected.

(l) Deutz F6L 714 diesel engine and Johnson Matthey exhaust purifier operated at 7/8 load, 2200 rpm.

(iii) To investigate the contribution of nitro compounds to the mutagenic activity of diesel exhaust particulates and to determine the extent of artifacts caused by sample exposure to exhaust gases by means of the nitroreductase deficient Salmonella tester strains.

3. DIESEL ENGINES TESTED (ORF)

The two engines used in the test programme at ORF were (i) a Deutz F6L 714 (Sn 4-841-927) diesel engine, rated at 101 Kw at 2300 rpm. This engine is air-cooled and incorporates a pre-combustion chamber for indirect injection of diesel fuel into each cylinder. Lower exhaust emissions are characteristic of indirect injection compared to direct injection engines of similar horse power ratings. Deutz engines, therefore, are in common use in underground mines at the present time; (ii) a Detroit DDAD 8V71N (SN 8VA-241122 7087-7517) two stroke diesel engine was also tested at ORF.

Engine testing at ORF was conducted using a Go-Power DT-1000 dynamometer to control engine load and speed.

Dynamometer testing was conducted at steady state condition, i.e., 7/8 load and 2200 rpm for the Deutz F6L 714 and 7/8 load, 2100 rpm for the Detroit diesel.

Testing of the Deutz F6L 714 engine was also conducted at full load and 1600 rpm. This work was carried out so that two points of the total LHD (load-haul-dump) cycle would be available to help in interpretation of cycle test data.

4. DYNAMOMETER SAMPLES (ORF)

A stainless steel dilution tube was designed (Figure 1), and used to collect samples of exhaust at a 16:1 dilution ratio. It was expected (1980/81 study) that dynamometer tests at a 16:1 dilution ratio would adequately model "real world" underground mutagen levels for both raw and catalytically treated diesel exhaust.

Samples of diesel particulates were collected for 30 minutes at a dilution ratio of 16:1 on 20 x 25 cm Pallflex filters (T60A20). The dilution temperature, measured at the filter, was allowed to vary between 48 and 51°C depending on the dilution air temperature. A Hi volume sample blower was the primary air moving system. The flow rate was approximately 0.566 m^3/min. (173/30 min.). Heating tape was wrapped around sample probe to the dilution tube to prevent or minimize sample losses due to condensation. A 20 x 25 cm Pallflex filter (T60A20) was attached directly in front of the blower to collect the particulates in the 16:1 diluted exhaust. The Pallflex filters were conditioned and weighed prior to use. The residence time for particulates in the 10 cm diameter tube was estimated to be approximately one second.

Under the sampling conditions and dilution ratio described, the nitrogen dioxide concentration level for raw exhaust is very low. Under conditions where oxidation catalysts are present and producing nitrogen dioxide, it is expected that the concentration will be below the 5 ppm level reportedly (4) required for introduction of sampling artifacts (production of nitro PAH's).

4.1 Dilution Ratio

Dilution sampling methods are frequently used in sampling diesel particulates. They allow for chemical mechanisms and agglomeration of the particulate materials to occur before collection on the filter. This method is intended to simulate "read world" conditions when diesel exhaust leaves the tailpipe. The amount of dilution is determined by measuring the gaseous component, carbon dioxide, at the tailpipe and the collection filter. The ratio of the concentration of the carbon dioxide is a measure of the amount of sample dilution.

The flow rate through the dilution tube was determined by measuring the blower static pressure with an inclined manometer. Calibration curves were obtained for the blower performance at various pressure drops.

5. SAMPLE COLLECTION AT LOCATIONS OTHER THAN ORF

The concentration of both PAH's and mutagenic substances in the environment are very low (nanogram per 1000 m^3 range) and therefore, a large volume of air must be sampled to provide sufficient material for analysis. All samples collected above ground, from the underground mine environment, and samples collected at the CANMET bunker in Ottawa, were obtained using large volume sampling methods.

5.1 Hi Volume Samples (5)

Samples are collected by drawing a large volume of air through an 20 x 25 cm Pallflex filter mounted on a Hi volume sampler. Particulates and aerosols in the air environment are collected on the Pallflex filters. This sampling method is 99.9% efficient for collection of particulates with a diameter as low as 0.3 microns.

The flow rate through the Hi volume samplers can vary from 40 to 80 cfm and the sampling times can range from 25 minutes to 36 hours. Most sampling times, however, were between 3 to 5 hours. The variation in sampling time and flow rate is a function of the concentration of particulates present in the environment and the rate at which the sampling filter blocks up. Sampling times were adjusted so that the flow rate through the filters remained reasonably constant (within 10% of the initial flow rate) during the sampling period. Flow rates were monitored, permitting calculation of the total volume sampled, so that results could be reported as concentrations (mg/m^3) or biological activity ($revertants/m^3$).

This procedure underestimates the total volume of air sampled and thus results in slightly higher concentrations of particulates and mutagenic activity. The difference is small when the flow rates are kept within 10% of the original value. No correction was made for this.

5.2 Underground Samples

Diluted exhaust from a Deutz F8L 714, 185 HP diesel engine was sampled underground at Falconbridge's Lockerby mine. This sampling programme was conducted during a period when the mine was not in production, however, ventilation and other mine systems were being operated as normal. The work in this programme was being carried out to confirm results obtained in the initial sampling programme for raw exhaust. (5) Some underground raw exhaust samples gave high values and it was suspected that these were due to contamination from a Dieseler III equipped diesel or perhaps some other mine activity taking place in the area during sampling.

The path taken by the diesel equipment is illustrated in Figure 2. The diesel powered vehicle carried ore in both directions. The pick-up near the sampling site (muck pile A) was a true mucking operation, i.e., the diesel pushed hard against the wall of the box hole as it picked up the muck. At the stope end, (muck pile B), the ore was dumped and then picked up from the pile again so there was no lug down.

Muck pile B was situated so that the exhaust ports of the diesel were always in the main drift, thus, little or no exhaust should have been lost into the stope. The exhaust ports of the diesel at muck pile A always remained in the main drift. The air flow in the drift was from right to left.

The Hi Vol. samplers were set up on one metre high barrels at the locations illustrated in Figure 2. Table 1 shows the concentrations of gaseous components measured during the sampling period. The gas concentrations were measured using draeger type tubes or draeger tubes. The time-weighted average CO_2 was obtained by GC analysis on a sample collected during the sampling period each day.

5.3 CANMET Samples, Ottawa

For this programme, the engines tested in the bunkers at CANMET's test facility in Ottawa, were, (1) a Caterpillar 3304 diesel operated at steady state conditions (7/8 load and 2200 rpm) and, (2) A Deutz F6L 912W indirect injection diesel engine. The Deutz engine was tested at two dilution ratios (vent fan high and vent fan low) both at steady state and for the load-haul-dump (LHD) cycle identified as the Inco cycle.

Samples were collected in the bunker using the Hi volume sampling methods described by Dr. Westaway.(5)

For a given diesel engine the steady state condition was selected to represent a possible worst case condition and the LHD cycle was chosen to simulate actual underground conditions. A comparison of the steady state and LHD cycle provides information regarding the maximum and actual mutagen levels expected to be encountered in the underground environment.

6. SAMPLE CHARACTERISTICS

The emissions from a diesel engine are composed of solid (insoluble soot), liquid (i.e., water, sulphuric acid, nitric acid), and gaseous (hydrocarbon compounds) components, and are very complex in character. The particulates are composed of the carbonaceous insoluble matter, containing adsorbed and condensed organic components from the combustion of fuel. The soluble organic fraction (SOF) of these particulates is extremely complex and has been reported to contain hundreds of individual compounds.(6)

The size distribution of diesel particulates has been studied using different engines, fuels and operating conditions (7) to obtain details of particulate formation mechanisms. It is important to note that fewer than 1% (8) of the particles are larger than 0.05 microns. Consequently, diesel particulates are easily transported by airstreams and are removed from air only by high efficiency filters.

Isokinetic sampling is not critical for particulates of the size range found in diesel exhaust. However, an effort was made to sample within 20% of the isokinetic rate.

6.1 Sampling Artifacts

The greatest potential problem in the sampling methodology is the generation of artifacts. The result of the formation of substances that do not exist in the natural situation or the elimination of substances that would normally exist are sampling artifacts. A number of investigations (9)(10) have demonstrated that mutagenic nitroaromatic compounds are contained in the unfractionated organic extracts of the diesel particulates collected on filters.

Diesel engines emit varying levels of NO_x gases that pass across the filters and collected particulates. There are basically three places where nitroaromatics may be produced.

ORF

(1) in the combustion process,

(2) in the exhaust process as organics interact and condense on the particles,

(3) in the filter collection process where particulates are exposed to gaseous components during sampling.

Although the extent and relevance of the artifact problem has not been fully resolved, bacterial mutagenicity testing has provided methods for examination and identification of the problem.

6.2 Handling and Storage

Samples for biological characterization were collected on Pallflex Corporation type T60A20 (20 x 25 cm) filters. The test filters were removed from the dilution tube, folded so that the particulates were on the inside of the filter, inserted into a polyethylene bag fitted with a twist tie and placed in a manilla envelope and stored at -70°C in a Revco freezer until extraction.

Samples collected in the field using Hi volume samplers are sealed in sterile polyethylene envelopes, placed on dry ice and shipped by overnight express bus to the laboratory for biological testing. All samples received using this system had sufficient dry ice remaining, insuring correct temperature was maintained during transportation. Samples collected in the laboratory were also stored at -70°C until extraction. A time lapse of 24 hrs. to 14 days was normal before samples could be assayed for mutagenic activity.

After extraction, the soluble organic extracts of the diesel particulates are stored for 8 hours at -20°C before mutagenic testing.

The effects of storage were examined (we have examined storage) both on collection filters, and as extracts stored in dimethylsulfoxide (DMSO) for periods up to 3 months. No significant variation in TA98 direct acting mutagenic activity was detected. It has been reported (11) that direct acting components increase in toxicity with storage. However, if the linear portion of the dose-response curves are compared, the effect of storage is minor. In no case did mutagenicity increase with storage.

Experiments carried out (12) to determine the effects of prolonged storage showed no significant variation in the mutagenic activity of the organic extracts from a Caterpillar or Oldsmobile diesel over an eight month period.

Sample filter and soluble organic extracts of samples for biological characterization were handled under yellow light (Westinghouse F40GO Gold) to eliminate the effects of ultra-violet radiation, normally associated with fluorescent lighting used in most laboratories.

6.3 Extraction

Filter samples of particulates are folded in thirds across the width and cut to afford maximum exposure of the particulates to the extraction solvent. The filters were then loosely rolled and placed into a cellulose extraction thimble (Watman 35-85mm) to contain particulates and prevent contamination of the extracts. A maximum of two (20 x 25 cm) filters were placed in each thimble to ensure efficient extraction. The particulate samples were then extracted with 160 mL of dichloromethane (DCM) (ACS reagent grade), using the Soxhlet extraction technique. Dichloromethane has been reported (13) to extract the largest quantity of biologically active organic material from diesel particulates. An extraction time of 16 hours at a rate of 3 to 4 exchanges per hour was used.

6.4 Concentration and Preparation of Extracts

Complete removal of the solvent used for extraction of the collected particulates is necessary in order to avoid toxicity to the Salmonella tester strains used in the mutagenicity assay and also to accurately weigh the extract. Solvent removal was accomplished by rotary evaporation at 30°C in a water bath. The volume of solvent was reduced to approximately 15 mL. The sample was then transferred to a weighed aluminum dish and the remaining solvent was removed under a stream of dry nitrogen. After drying, the total extract was weighed. The dry extract was then dissolved in DMSO to a known concentration and submitted for mutagenicity testing. This modification in methodology resulted in a more accurate estimation of the concentration of the soluble organic fraction and eliminated most of the toxicity to the Salmonella tester strains previously encountered.

6.5 Amount of Whole Diesel Particulates Extract Required for Mutagenicity Testing

The amount of sample required is a function of:

(a) the concentration range to be tested,
(b) the number of replicates tested at each concentration,
(c) the number of Salmonella tester strains,
(d) the requirement for metabolic activation, and
(e) the number of data points required to establish the linear portion of the dose-response curve.

We have determined from experience and from the literature (14)(15) that the range of mutagenic activity for whole diesel exhaust is between 10 and 1000 micrograms per plate. The linear portion of the dose-response curve normally occurs between 50 and 500 micrograms per plate.

The "ideal" mutagenicity assay would consist of three replicates per dose level and cover the range of concentrations between 50 and 1000 micrograms of extract per plate in 50 or 100 microgram units. Therefore, to conduct a single strain "ideal" assay 22 milligrams of extract is required to properly characterize the mutagenic activity of whole diesel exhaust particulates for each strain. For each additional strain, an additional 22 milligrams of extract is required. Samples requiring assay both with and without metabolic activation would require 44 milligrams of extract for each Salmonella tester strain used. Smaller amounts of extract can be tested by using less replication and fewer concentrations. However, whenever possible we recommend the "ideal" mutagenicity assay be performed.

7. MUTAGENICITY TESTING

The assay system used in this study was the Salmonella typhimurium plate incorporation assay method developed by Dr. Bruce Ames, et al.(16)

Briefly, 2 mL of molten top agar containing trace amounts of histidine and biotin were added to sterile tubes and the tubes were placed into a dry block maintained at 45°C. To each tube was then added 0.1 mL of a Salmonella tester strain and a known concentration of sample extract. In experiments where metabolic activation was required, 0.5 mL of the metabolic activation mixture (S-9) was added. Each tube was mixed and poured on to minimal agar plates. Uniform distribution of the top agar on the surface of the plates was accomplished by tilting and rotating the plates. Plates were then incubated in the dark at 37°C. After 48 hours, 72 hours in the case of the nitroreductase deficient strains, the histidine independent colonies on both the test and control plate were counted. Colonies are counted under a binocular microscope. When the number of colonies exceeds 2000 per plate, the colonies in five one centimeter squares are counted and the results are multiplied by a factor. This makes all numbers in excess of 2000 an estimate, while numbers less than 2000 are actual counts. In addition, the density of the background lawn was visually evaluated for toxicity. Stock cultures were maintained and characterized according to procedures described by Ames et.al. Quintuplicate platings were conducted for negative control plates. Triplicate platings were conducted, where sufficient sample extract was available.

7.1 Theory (How the Assay System Detects Mutagenic Materials)

The assay uses mutant strains of the bacterium Salmonella typhimurium. Each strain contains a point mutation in the gene coding for histidine biosynthesis. This results in a defective enzyme in the histidine biosynthetic pathway. The mutant Salmonella strains are unable to grow on media which do not contain histidine. In addition to the histidine mutation, each tester strain contains structural modifications. One such modification enables agents to permeate more easily into the bacteria. A second alteration interferes with the bacteria's genetic repair mechanism. This permits the action of the mutagen to be expressed and thus detected by the assay.

Exposure of the tester strains to substances which can alter genetic activity (mutagens) results in a reverse mutation. Some of the mutant cells (requiring histidine his-) revert back to their wild type (able to synthesize histidine his+) state. In the process, the bacteria regain the ability to synthesize histidine and now will be detected as colonies of histidine-free media. Positive known mutagens are often used to monitor strain response.

7.2 Genetic Activity

The major type of genetic alteration detected by the Ames test is gene mutation. Gene mutations are changes in the structure of DNA in individual genes; the term point mutation is also used, particularly if it is known that the mutational change is restricted to a single gene. Gene mutations include base-pair substitutions, in which one base-pair in DNA (Adenine-Thymine) is replaced by another (Guanine-Cytosine), and frameshift mutations, in which one or a few base-pairs are added to or deleted from the structure of DNA.

7.3 Base-Pair Substitution Mutations

The altered base sequence that results often leads to a change in amino acid sequence in the protein that is encoded by the gene. The altered protein may function differently from the original protein, thereby causing a difference in the characteristics of the organism.

7.4 Frameshift Mutations

A frameshift mutation alters all of the genetic information after the point in the DNA at which a base-pair is added, deleted, or shifted. Consequently, frameshift mutations lead to grossly altered and nonfunctional gene products. Frameshift mutations and some base-pair substitutions can also cause incomplete and nonfunctional genes because the newly generated base sequence can contain units of genetic information that specify no amino acid at all. The effect of such mutations depends upon the consequences of the missing gene function in the biochemistry of the affected organism.

Some mutagens exhibit specificity for particular mechanisms of mutagenesis. The metabolites of benzo(a)pyrene for example, induce predominantly frameshift mutations, whereas, diethyl sulfate primarily induces base-pair substitutions. Other mutagens, such as ultra violet light, induce a mixture of alterations. It is, therefore, important that tests for mutagenicity be able to detect both base-pair substitutions and frameshift mutagens.

7.5 Metabolic Activation

Mammalian-microsomal enzymes are often used in the assay's reaction mixture (S-9). These enzymes serve as part of the metabolic activation complex, which also includes compounds that aid in electron transport and energy production. The activation complex is sometimes needed as many substances which are non-mutagenic outside animal systems are structurally altered to a mutagenic form by metabolic processes within animal tissues.

Since Salmonella do not inherently possess these metabolic enzymes, the reaction mixture must be supplemented. However, microsomal enzymes have inhibitory as well as activating properties. Therefore, in most instances, when a substance is tested it must be tested in the presence and absence of the metabolic activation complex.

7.6 Mutagenic Potency (Pure Compounds)

The frequency at which the tester strains revert to the wild type depends upon several factors, one of which is the mutagenic potency of the agent tested. Mutagenic agents which are highly potent will induce a greater number of bacteria to revert back to the wild type than will agents which produce less mutagenic damage. The number of colonies induced by a mutagenic substance, at a given dose, (revertants/nanomole) provides a measure of the potential hazard of the substance.

Detecting mutagens in environmental samples introduces complications beyond those encountered in screening pure compounds; mixtures often have variable or inadequately known chemical compositions, and the biological effects of mutagens in complex mixtures are not necessarily additive. In addition, chemicals in complex mixtures need not act additively in their mutagenicity; rather, there may be synergism or antagonism between mutagens, or interactions between mutagens and non-mutagens.

Mutagenic potency for complex mixtures can not be determined in terms of revertants/nanomole because the chemical composition is unknown. However, a relative mutagenic potency (specific activity) can be determined in terms of revertants/microgram of the complex mixture and is useful for comparing different samples (see specific activity).

7.7 Positive Mutagen

A positive result is defined as a reproducible, dose-related increase in the number of histidine-independent colonies. Positive control compounds with known mutagenic responses are included with each assay to ensure that the assay is functioning properly.

7.8 Toxicity

Toxicity is determined by visual evaluation, using a binocular microscope, of the background lawn on the test plates. The sample concentrations were plated with 10^8 cells on minimal agar plates which contain trace amounts of histidine and biotin. The trace amounts of histidine allows mutant cells to divide once or twice in order to express their mutation. However, once the trace histidine has been depleted, only those cells which have become histidine independent will form colonies. The growth on the plate of the remaining non-colony forming cells, i.e., those which have not reverted back to the histidine independent state, represents the background lawn.

By visual evaluation of the density of the background lawn, the dose at which the test material begins to show toxicity can be estimated. This estimation was made by comparing the lawn on those plates containing no sample extract (control plates) with the background lawn on those plates containing various concentrations of sample extract. Only those concentrations where no toxicity was evident were used for assessing the mutagenic activity of the samples. However, at least one concentration showing toxicity should be examined because of the relationship between mutagenicity and toxicity to ensure a positive mutagenic response has not been missed.

7.9 Net Revertants (Revertants/Plate)

The net revertants per concentration were calculated using the average revertants per plate for the replicates at each of the concentrations examined minus the average revertants per plate for the replicates of the negative background controls.

7.10 Specific Activity (17) (Revertants/Microgram)

The specific activity for the soluble organic fraction of whole diesel exhaust was calculated by taking the slope of the linear portion of the dose-response curve.

The specific activity is simply a convenient method of comparing the relative mutagenic potency of different sample extracts that are composed of a complex moisture of chemical constituents. A least square curve fit of the linear portion of the dose-response curve was calculated using the net revertants at each dose level. The lower concentration of the linear portion of the dose-response curve was determined by comparison of the curve fit at each of the data points. Data points which showed a departure from linearity at high does were rejected. The upper limit of the dose-response curve was taken to be either the highest dose tested or the point where toxicity became apparent.

7.11 Total Activity (18) (Revertants/Mass)

The total activity of each sample extract, in units of thousands of revertants, was determined by multiplying the extract mass (milligrams of SOF) by its specific activity.

7.12 Mutagen Density (19) (Revertants/Cubic Metre)

The mutagen density of each sample was calculated by dividing the total activity by the sample volume, and is expressed as revertants per cubic metre. The mutagen density calculated for underground samples corresponds directly to the dose of mutagenic material (as defined by the Salmonella tester strain) available for inhalation by the mineworker.

7.13 Total Mutagenicity (Revertants/M^3 Raw Exhaust)

The total mutagenicity at the tailpipe is determined by multiplying the sample mutagen by the dilution ratio. This information is useful when comparing samples collected under different conditions. This allows engine dynamometer samples collected in the laboratory to be compared with Hi Volume samples collected in the underground mining environment.

7.14 The Salmonella Tester Strains

There are several *Salmonella* tester strains containing different types of histidine mutations (see Table 2). The initial development of methods, and application of mutagenicity testing to whole diesel exhaust particulate samples was performed using the five original *Salmonella* tester strains, both in the presence and absence of metabolic activation (S-9).

The *Salmonella* tester strains TA1535, TA100, TA1537, TA1538 and TA98, were obtained from Dr. Bruce Ames of the University of California, Berkeley and were those recommended for general mutagenicity testing by the Environmental Mutagen Society(20).

Each *Salmonella* tester strain contains several mutations, first a mutation in the histidine operon resulting in a requirement for histidine. A second mutation, a deletion through the uvrb region of the chromosome eliminates the excision repair system for DNA, allowing the effects of a mutation to be detected. A third mutation through the gal and rfa (Deep Rough genes), eliminates, to a different extent, the polysaccharide side chains of the lipopolysaccharide that coats the bacterial surface, making the bacteria more permeable to larger molecules. The addition of the R-factor plasmid pKM101 to TA98 and TA100 resulted in an increased sensitivity for certain classes of mutagens, possibly because of the error-prone SOS recombinational repair system. The addition of the plasmid also caused the tester strains to become ampicillin resistant.

All *Salmonella* tester strains are regularly examined to determine the presence of the genetic markers. Tester strain cultures for each experiment are prepared to a known cell density (2×10^8 organisms/mL). It is important to start with approximately the same number of cells each time because the spontaneous revertant (negative control) is a function of the number of cells available for mutation. Positive control tests using known mutagens, are conducted with each experiment to monitor the assay's ability to detect and quantify mutagens and to demonstrate that the assay system is functioning properly.

7.15 Tester Strains Employed in Routine Mutagenicity Testing

TA1535:	a HIS G46 strain used in the detection of mutagens inducing base-pair substitutions.
TA1537:	a HIS C3076 mutated strain used in the detection of mutagens capable of causing frameshift mutations.
TA1538:	a HIS D3052 mutated strain used to detect mutagens that cause frameshift mutations.
TA98:	a TA1538 strain into which a pKM101 episome has been added. This strain is more sensitive in detecting frameshift mutations than is tester strain TA1538.
TA100:	a TA1535 strain into which the pKM101 episome has been introduced. This tester strain provides a more sensitive system for detecting base-pair substitutions than can be obtained with TA1535. However, because of the SOS error-prone repair system, this strain also responds to some frameshift mutations, usually to a lesser extent than TA98.

The five original Salmonella tester strains are known to respond to a wide variety of known mutagens/carcinogens and were therefore employed in the initial screening program. Testing was carried out both in the presence and absence of the metabolic activation mixture (S-9) and was designed to provide sensitive detection of a wide variety of mutagens. The working hypothesis was that sensitive detection of mutagens and potential carcinogens associated with diesel exhaust particlulates could be used to isolate and identify potential areas of hazard to man. In addition, the information could be helpful in establishing priorities for further testing or for developing and evaluating exhaust treatment devices.

The Salmonella tester strains routinely employed for mutagenicity testing have bacterial enzymes which can activate some chemicals to reactive intermediates.

Tester strain TA98 responds to frameshift mutagens and has been found to be the most sensitive strain for detecting the direct acting mutagens present in the soluble organic fractions (SOF) of extracts from whole diesel particulates. The term direct acting is used only to denote the face the metabolic activation mixture was not required for expression of mutagenic activity. The Salmonella tester strain TA98 has been found to be especially sensitive for detection of nitro-containing mutagens (nitrated polycyclic aromatic hydrocarbons: Nitro-PAH's). Normally PAH's required metabolic activation with S-9 to be detected as mutagens by TA98. However, nitro-substituted PAH's appear to be activated to positive mutagens by the nitro-reductase enzyme systems present in the Salmonella tester strains.

Nitro-substituted chemicals as a class are modestly potent bacterial mutagens and it has been suggested that their potency reflects the active nitro-reductase enzymes present in Enterobacteriaceae(21). Nitro-pyrenes are apparently transformed to biologically active intermediates by nitroreductases. It might well be that their potent mutagenic activities in bacteria reflects the activity of these possibly unique bacterial enzymes.

It is unknown whether the potent mutagenic activity associated with nitrated polycyclic aromatic hydrocarbons reflects purely a microbial characteristic or whether nitro-PAH's from diesel exhaust constitutes a "real" and significant risk to man and the environment.(22)

Three nitroreductase deficient mutant strains of Salmonella typhimurium (TA98NR, TA98/1,8DNP$_6$, TA98/NR/1,8DNP$_6$) were used to assess the mutagenicity of diesel exhaust emissions during the second study programme. The nitroreductase deficine strains which were derived from TA98, were obtained from Dr. Herbert Rosenkranz at Case Western Reserve University, Cleveland, Ohio.

ORI

When sufficient extract was available, samples were tested on TA98 and the three nitroreductase deficient strains. No metabolic activation was used with the nitroreductase deficient Salmonella strains, as it contains nitroreductase enzymes and would negate the effect of removing the nitroreductase enzyme system from the Salmonella tester strains.

It was expected that the new tester strains would allow us to sort out the effects of the NO_2-PAH's on the total mutagenic activity of the extracts and would be useful in evaluating the possible formation of artifacts during sampling.

The three nitroreductase deficient TA98 Salmonella tester strains TA98NR, TA98/1,8DNP$_6$, TA98/NR/1,8DNP$_6$ all contain the histidine D3052 mutation, as well as the uvrb and rfa mutations and also include the R-factor pKM101 plasmid. In addition, these strains contain mutations which interfere with two different nitroreductase enzymatic pathways.

Tester strain TA98NR lacks the "classical" nitroreductase enzyme required for expression of the mutagenicity of nitrofluorenes, nitronaphthalenes, nitrofluorenes, etc., and appears fully responsive to non-nitrated frameshift mutagens and also to the mutagenic action of some of the nitroarenes that might be present in diesel exhaust emissions (e.g., nitropyrne, dinitropyrene, and other nitrated polycyclic aromatic hydrocarbons). In tester strains TA98 and TA98NR, the successive addition of nitro groups results in increased mutagenic activity which reaches a maximum with 1,3,6-trinitropyrene and then declines with 1,3,6,8-tetranitropyrene.(23) Such a finding was also made with the nitrofluorene series.(24)

The Salmonella tester strain TA98/1,8DNP$_6$ is a derivative of TA98 which lacks the nitroreductase enzyme required for the expression of the mutagenicity of 1,8 dinitropyrene. This strain also shows a lack of response to the action of 1,3-dinitropyrene and a greatly reduced response to 1,6-dinitropyrene and 1-nitropyrene. The response to 1,3,6-trinitropyrene and 1,3,6,8-tetranitropyrene is affected to a much lesser extent. Tester strain TA98/1,8DNP$_6$ is fully sensitive to the mutagenic action of 4-nitroquinoline-1-oxide, niridazole, nitroacridine, and non-nitrated frameshift mutagens. This strain appears to be deficient in a nitroreductase which reduces nitrated pyrenes and possibly other multi-nitrated polycyclic aromatic hydrocarbons to their corresponding mutagens.(25)

Tester strain TA98/NR/1,8DNP$_6$ is a double mutant and lacks both of the previously described nitroreductase enzyme systems while retaining full sensitivity of 4-nitroquinoline-1-oxide and other non-nitrated frameshift mutagens.(26)

8. RESULTS AND DISCUSSION

8.1 Dilution Ratio Selection and Approval (Task 1A)

The final report (ORF 81-1) issued under DSS Contract Number 1SQ80-00045 revealed some anomalies in the results for the dilution tube tests. Non-catalyst test results showed 26, 24 and 27 percent soluble material for 13:1, 9:1, and 16:1 dilution ratios, respectively. Catalyst tests results, however, gave 29, 21 and 27 percent soluble material for the same dilution ratios, respectively. These results did not appear to follow expected trends since it was felt that the catalyst results should show a reduced soluble organic fraction. Due to the limited number of tests carried out in Phase I of the above contract a conclusion on catalyst effects on the soluble organic fraction could not be made. It was decided that further work be performed in Phase II. This section gives results of the SOF investigation.

Particulate sampling was carried out using a dilution tube *basically similar to that used in Phase I. A Teco, chemiluminescent* NO_x analyser was used to measure real-time NO_x concentrations in the engine exhaust and the dilution tube gas. Dilution ratios were calculated by dividing the exhaust gas NO_x concentration by the dilution tube NO_x concentration. Temperatures of both exhaust banks, diluted exhaust, engine intake air and the control room were measured using thermocouples. PTX, type 6DF exhaust purifiers (one for each engine bank) were used for the catalyst tests. Following particulate sampling filters were weighed to determine the total particulate material. Filters were then extracted with dichloromethane to remove the soluble organic fraction. The filter extract was then evaporated to dryness in aluminum dishes of a known tare weight. Following evaporation, the aluminum dish was reweighed to determine the soluble portion. In the case of catalyst tests, the particulate filters were extracted with water following the dichloromethane extraction. This second extraction removed the sulphate material in order to determine the insoluble particulate material on the filter.

Table 3 gives results of the test conditions observed during the dilution tube tests. Engine conditions during these tests were 2300 RPM, 86 kW (7/8 load). Test numbers 1 to 4 were conducted at 13.1:1 dilution ratio. The average exhaust NO_x concentration was 670 ppm and the average dilution tube temperature was 45°C. Test numbers 5 to 9 were carried out at an average dilution ratio of 9.0:1. During these tests the exhaust NO_x concentration averaged 690 ppm and the dilution tube temperature increased to an average of 58°C.

Test numbers 10 to 20 (catalyst tests) were conducted at an average dilution ratio of 13.1:1 while the average exhaust NO_x concentration dropped to 618 ppm. It is felt that the lower NO_x concentration is attributable to the catalyst. The average dilution tube temperature for test numbers 10 to 20 was determined to be 43°C.

Table 4 gives results of the particulate tests conducted at 13:1 and 9:1 for non-catalyst tests and at 13:1 for catalyst tests. The average soluble concentration (corrected to engine exhaust) was 14.7 and 13.3 mg/m^3 for dilution ratios 13.1:1 and 9.0:1, respectively. These results are in the range of those presented in Phase I for similar test conditions. Insoluble particulate concentrations averaged 30.8 mg/m^3 for 13.1:1 dilution ratio and 27.4 mg/m^3 for 9.0:1 dilution ratio for the non-catalyst tests. The insoluble concentrations are somewhat lower than that found in Phase I and may be due, in part, to cleaner combustion during the later tests.

Based on the above results, the percentage of soluble material of the total particulate (excluding sulphate) was 32.3% and 32.7% for dilution ratios of 13.1:1 and 9.0:1, respectively.

The average soluble concentration decreased to 5.7 mg/m^3 for the catlayst tests (10 to 20) while the insoluble concentration averaged 20.7 mg/m^3. This results in an average of 21.9% soluble of the total particulate material excluding sulphates. This result compares with the 21% solubles found in Phase I for the 9.5:1 dilution ratio.

Following a presentation of the results to the Scientific Authority, approval was received to continue testing on the following tasks at a 16:1 dilution ratio.

8.2 Raw (non-treated) Whole Diesel Exhaust

8.2.1 Deutz F6L-714 Diesel Engine

The *Salmonella* mutagenicity test data for the Deutz F6L-714 engine at steady state (7/8 load, 2200 rpm) are presented in Tables 5, 6, 7, and 8. Four *Salmonella* mutagenicity tests were carried out using tester strain TA98 without metabolic activation, to provide information on reproducibility of the sampling and testing system. Two of the samples were also tested using the nitroreductase deficient *Salmonella* tester strains. An evaluation of raw data for each test is presented in Tables 5A, 6A, 7A, and 8A.

The soluble organic fraction, when calculated in terms of undiluted exhaust, gave values of 16.5, 12.1, 16.4 and 57.4 mg/m^3. The value 57.4 is high and is due to the presence of oil on the high volume collection filters. When an engine is emitting large amounts of oil in the exhaust it is not possible to obtain a good value for the SOF because the oil is extracted by the DCM and is therefore part of the SOF. With the exception of the one sample filter where the oil was apparent the values for the SOF are in good agreement.

Sufficient sample was available to conduct four strain (TA98, TA98NR, TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$ without S-9) assays in two of the engine runs and the other two runs were tested with TA98 without metabolic activation only. The specific activities from Tables 5, 6, 7 and 8 respectively for TA98 without S-9 were 1.598, 0.975, 0.891 and 0.303 revertants per microgram. The low specific activity value (0.303 revertants/µg) is from the sample containing oil. This was anticipated because, as explained previously, it was not possible to obtain an accurate soluble organic fraction weight due to presence of oil in the DCM extract.

The specific activities from Tables 5 and 6 for (a) TA98NR were 0.475 and 0.58 respectively, (b) for TA98/1,8DNP$_6$ were 0.10 and 0.22, (c) for TA98/NR/1,8DNP$_6$ were 0.0975 and 0.06.

When the total mutagenicity of the samples was compared (based on raw exhaust) reasonable agreement was found for the TA98 without S-9 for all four sets of data. Tables 5, 6, 7, and 8 showed 26,432, 11,786, 14,591, 17,392 revertants per cubic metre of undiluted exhaust. The total mutagenicity for TA98NR is 7,857 for Table 5 and 7,029 for Table 6. Salmonella tester strain TA98/1,8DNP$_6$ gave results of 1654 and 2666 revertants/m^3 of undiluted exhaust and TA98/NR/1,8DNP$_6$ yielded 1571 and 727 respectively for Tables 5 and 6.

The average total mutagenicity value for a Deutz F6L 714 diesel engine at steady state (7/8 load, 2200 rpm) for TA98 is 17,553 revertants per cubic metre of undiluted exhaust.

8.2.2 Deutz F6L 912W Diesel Engine

The mutagenicity data for the Deutz F6L 912W diesel engine at steady state (7/8 load, 2200 rpm) collected at CANMET's engine testing facility, are presented in Tables 9 and 10, for vent fan low and high respectively. Two tester strains, TA98 and TA98NR, both without metabolic activation, were employed to examine the exhaust of the Deutz F6L 912W engine under the two vent fan conditions. The raw data appears in Tables 9A and 10A. The soluble organic fraction, when expressed as undiluted exhaust, gave values of 37.0 and 55.0 mg/m^3.

The specific activities for TA98 from Tables 9 and 10 respectively were 0.72 and 0.51. For TA98NR the specific activity for Table 9 was 0.33 revertants per µg and Table 10 was negative.

The total mutagenicity for TA98 without S-9 was 26,626 and 28,059 revertants/m^3 for the results in Table 9, while the results in Table 10 showed a negative mutagenic response.

These results indicate good replication for TA98 at both dilution ratios (32:1 and 76:1 for Tables 9A and 10A respectively) and are similar to other Deutz engine results, i.e., F6L 714 engine average 17,553 revertants per cubic metre of undiluted exhaust. The values for TA98NR show inconsistencies for which there is no explanation at the present.

8.2.3 Caterpillar 3304 Diesel Engine

The *Salmonella* mutagenicity assay results for the Caterpillar 3304 diesel engine at 7/8 load and 2200 rpm (steady state) are shown in Tables 11 and 12. Two tests were carried out: one used four tester strains TA98, TA98NR, TA98/1,8DNP$_6$, and TA98/NR/1,8DNP$_6$ without metabolic activation; the other had sufficient sample for only two strains - TA98 and TA98NR without S-9.

The soluble organic fraction, in terms of undiluted exhaust, was 34.5 mg/m^3 in Table 11A and 55.4 mg/m^3 in Table 12A. The specific activity for TA98 without S-9 in Table 11 was 1.35 and in Table 12 was 1.24. For TA98NR the specific activities were 0.81 and 0.60 revertants/µg respectively for Table 11 and 12. The sample in Table 11 gave negative mutagenic responses for TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$ without S-9.

The total mutagenicity for TA98 without S-9 was 46,611 and 68,696 revertants/m^3 undiluted exhaust. The average of these two results is 57,654. The average total mutagenicity for TA98NR without S-9 from Table 11A and Table 12A is 30,603. Table 11 data shows a negative mutagenic response for TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$.

These two sets of filters, collected at the same time, were assayed approximately six months apart. The data shows good replication indicating minimal changes take place at -80°C storage for unextracted filters.

8.2.4 Detroit DDAD 8V71N Diesel Engine

Table 13 presents the *Salmonella* mutagenicity assay results for TA98 with and without S-9, TA98NR, TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$ without S-9 only for the DCM filter extracts from the Detroit DDAD 8V71N diesel engine at 7/8 load, 2100 rpm (steady state). The raw data for this engine is presented in Table 13A. The soluble organic fraction was 19.8 mg/m^3 based on undiluted exhaust. The specific activities for all strains tested were negative and thus, the total mutagenicity (expressed as revertants per m^3 raw exhaust) was negative.

This engine gave the lowest mutagenic response of all of the engines we have tested to-date.

8.2.5 Deutz F6l 714 Diesel Engine at 1600 rpm, Full Load

The *Salmonella* mutagenicity test data for the Deutz F6L 714 engine at 1600 rpm and full load are presented in Tables 14, 15 and 16. Three *Salmonella* mutagenicity tests were conducted using tester strains TA98 and TA98NR without S-9. One of the three tests also included TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$ without metabolic activation. An evaluation of the raw data is given in Tables 14A, 15A and 16A.

The soluble organic fractions were measured as 7.3, 8.0, and 3.3 mg/m^3 of raw exhaust. The 3.3 value from Table 16A is lower than the other two SOF values.

The specific activities for TA98 without S-9 were 0.43, 0.41, and 0.27 revertants per µg for Tables 14, 15, and 16 respectively. Again, the value from Table 16, 0.27 revertants/µg was lower than the values for Tables 14 and 15. The revertants per µg for TA98NR without S-9 were 0.07, 0.07 and 0.15 for Tables 14, 15 and 16. Table 16A data includes 0.07 and 0.18 revertants/µg for TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$ respectively.

The total mutagenicity expressed in revertants per cubic metre for TA98 without S-9 was 3165, 3280 and 904 for Tables 14, 15, and 16. For TA98NR the total mutagenicity was 515, 560, and 503 for each of the Tables mentioned. TA98/1,8DNP$_6$ had a total mutagenicity of 235 while the TA98/NR/1,8DNP$_6$ value was 603. The average total mutagenicity with TA98NR without metabolic activation was 526.

The sample reported in Tables 16 and 16A is believed to be an outlier. We believe the other results obtained at these sampling conditions (Deutz F6L 714 Diesel Engine at 1600 rpm, full load) are more representative.

8.2.6 Deutz F6L 912W Diesel Engine Operated at CANMET under the INCO Load/Haul/Dump Cycle

Tables 17 and 18 present the data for the Deutz F6L 912W diesel engine tested at CANMET under Inco's Load/Haul/Dump (LHD) cycle. Table 17 presents the data for the Deutz F6L 912W engine running with the vent fan set on low and Table 18 shows the data for the engine with the vent fan on high. The *Salmonella* mutagenicity assay was run with two tester strains, TA98 and TA98NR without metabolic activation, on both samples from CANMET.

The soluble organic fraction for the vent fan low (Table 17A) was 47.4 and for the vent fan high was 35.2 mg/m^3 of raw exhaust.

The specific activity for Table 17, TA98 without S-9 was 0.41 and for Table 18, 0.36. Both samples gave negative mutagenic response for TA98NR without S-9.

The total mutagenicity for the Deutz F6L 912W engine vent fan low was 19,432 and for the same engine, but vent fan high, the value was 12,683. The average total mutagenicity was 16,058. The TA98NR total mutagenicity values for both samples were negative.

8.2.7 Deutz F8L 714 Diesel Engine Tested by Laurentian University Underground (mine not in production)

Table 19 and 20 present the data compiled from the *Salmonella* mutagenicity testing of the two samples received from Laurentian University of a Deutz F8L 714 diesel engine in operation underground (mine not in production). The DCM extracts of the two samples were tested with four *Salmonella* strains, TA98, TA98NR, TA98/1,8DNP$_6$, TA98/NR/1,8DNP$_6$ without metabolic activation. The raw data is presented in Tables 19A and 20A. The soluble organic fractions were 21.3 mg/m^3 from Table 19A and 29.98 mg/m^3 from Table 20A.

The specific activity derived for TA98 without S-9 from Table 19 was 0.29 and from Table 20 was 0.19. The specific activities for TA98NR without S-9 were 0.09 and 0.10 from Tables 19 and 20 respectively. TA98/1,8DNP$_6$ without S-9 had a specific activity of 0.08 shown in Table 18 but no mutagenic response as shown in Table 20. TA98/NR/1,8DNP$_6$ did not elicit any mutagenicity as shown by the data in either table when tested without metabolic activation on the DCM extracts from the Deutz F8L 714 diesel engine underground emissions.

The total mutagenicity is recorded as 6,173 in Table 19 and 5,698 in Table 20 for TA98 without metabolic activation. The average is 5,936 revertants/m^3 undiluted exhaust. For TA98NR without S-9 the mutagenicity was 1917 and 2998 averaging to 2458 revertants/m^3 undiluted exhaust. Table 19A had a total mutagenicity value of 1704 revertants/m^3 while the results shown in Table 20A had a negative mutagenic response for TA98/1,8DNP$_6$. The strain TA98/NR/1,8DNP$_6$ was negative in response as shown in both Tables.

8.3 Catalyst Treated Whole Diesel Exhaust

8.3.1 Deutz F6L 714 Diesel Engine and PTX Catalyst at 7/8 Load and 2200 rpm

This engine and catalyst combination was tested three times and the Salmonella mutagenicity assay results appear in Tables 21, 22, and 23. Table 21 shows results for TA98 with and without metabolic activation, TA98NR, TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$ without S-9 only. Table 22 contains the results for TA98, TA98NR, TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$ without S-9 only. Table 23 contains the data for Deutz F6L 714 engine and PTX catalyst DCM extracts for TA98 without S-9 only.

The soluble organic fractions for Tables 21, 22, and 23 were 27.5, 9.6 and 32.8 mg/m^3 raw exhaust. Though the SOF (Table 22) was low (9.6 mg/m^3) the specific activity was high and when the total mutagenicity was calculated, the value for the test shown in Table 22 was very close to the average of the three tests for TA98 without S-9.

The specific activity for TA98 without S-9 was 4.01, 7.81 and 0.93 for Tables 21, 22, and 23. The sample from the test shown in Table 21 was the only sample to have TA98 with S-9 included. The specific activity value was 1.7 revertants per µg. The values for TA98NR without S-9 from Tables 21 and 22 were 1.77 and 2.64. For TA98/1,8DNP$_6$ the specific activities were 0.128 and 0.328 and for TA98/NR/1,8DNP$_6$ 0.073 and 0.18 respectively for the tests shown in Tables 21 and 22.

The total mutagenicity for TA98 without S-9 for tests shown in Tables 21, 22, and 23 were 110,131, 74,976 and 44,608. The average total mutagenicity was 76,572 revertants per cubic metre of undiluted exhaust. The test data shown in Table 22 had the only value for TA98 with S-9, 46,689 revertants/m^3 undiluted exhaust. TA98NR without S-9 had a total mutagenicity of 48.611 for tests shown in Tables 21 and 25,344 for Tables 22. For TA98/1,8DNP$_6$ the values were 3,515 and 3,149 and for TA98/NR/1,8DNP$_6$ 2,005 and 1,728 for data shown in Tables 21 and 22 respectively.

The average total mutagenicities were 36,978 for TA98NR without S-9, 3,332 for TA987/1,8DNP$_6$ and 1,867 revertants for TA98/NR/1,8DNP$_6$ per cubic metre undiluted exhaust.

8.3.2 Deutz F6L 714 Diesel Engine and PTX Catalyst at 7/8 Load, 2200 rpm and 1/5th Sampling Time per Filter

Table 24 presents the raw data for the Deutz F6L 714 and PTX catalyst at 7/8 load, 2200 rpm with one fifth sampling time. Four strains were tested with the extracts from this sample: TA98 with and without S-9, TA98NR, TA98/1,8DNP$_6$ and TA98/NR/1,8DNP$_6$ without S-9.

The soluble organic fraction extracted from these filters was 27.1 mg/m^3 raw exhaust. The specific activity values expressed as revertants/µg were 2.28 for TA98 without S-9, 1.24 for TA98 with S-9, 0.696 for TA98NR without S-9, 0.098 for TA98/1,8DNP$_6$ and 0.030 for TA98/NR/1,8DNP$_6$ without S-9.

The total mutagenic response for TA98 without S-9 with 6 minutes/filter collection time was 61,863, approximately 15,000 revertants/m^3 undiluted exhaust less than the same engine with the PTX catalyst at 7/8 load 2200 rpm (i.e., Table 21, 22, and 23) with 30 minutes per filter collection time.

The reproducibility of the three samples tested showed differences greater than 15,000 revertants per cubic metre. Therefore, it is not possible to conclude, with the limited data, if the difference represents the presence of sampling artifacts due to the longer exposure time of the particulates to the exhaust gases.

8.3.3 Deutz F6L 714 Diesel Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm

Tables 25 to 34 present the data for the Deutz F6L 714 diesel engine equipped with a Dieseler III catalyst run at 7/8 load, 2200 rpm (steady state). Three tables contain data obtained with the unheated probe (Tables 29, 30, and 34) while the remaining Tables contain data obtained with the probe heated.

The tables of most interest were Tables 29 and 30. The soluble organic fractions were 8.3 and 8.5 mg/m^3 respectively. The specific activities for TA98 without S-9 were 50.79 and 13.47 which calculated into total mutagenicity values of 423,873 and 114,096 revertants per cubic metre of raw exhaust. The total mutagenicity for TA98NR without S-9 was 326,480 from Table 29 and 78,097 revertants/m^3 undiluted exhaust from Table 30. We speculate that the collection of highly active components, i.e., dinitropyrenes, is more efficient at or below 40°C (rather than normal heated conditions approximately 53°C) and this may result in artifacts due to collection temperatures.

The other tables reflect data that show the Dieseler III catalyst is storing its emissions, i.e., PAH's rather than dumping them as indicated by the data in Tables 29 and 30. The high mutagenic response values of Tables 29 and 30 reflect the "real world" conditions.

8.3.4 Deutz F6L 714 Diesel Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Not Heated. Storage Effect Examined

Table 34 presents the data compiled for the *Salmonella* mutagenicity testing of the Deutz F6L 714 diesel engine and Dieseler III catalyst at 7/8 load, 2200 rpm, probe not heated. Each sampling interval of half an hour was separated by a half-hour period at rated speed and half-load during which no samples were collected (to evaluate soot storage effects). The DCM extract was tested with two *Salmonella* tester strains, TA98 and TA98NR without metabolic activation. The raw data are presented in Table 34A. The soluble organic fraction was 7.5 mg/m^3.

The specific activity was 8.75 revertants/µg for TA98 and 4.84 revertants/µg for TA98NR.

The total mutagenicity expressed in revertants per cubic metre of undiluted exhaust was 65,338 for TA98 and 36,117 for TA98NR. Due to the lack of replicate samples for testing, it is not possible to reach any firm conclusions; however, the data we have obtained tends to confirm our suspicions that this catalytic device, under steady state conditions, stores mutagens.

8.3.5 Deutz F6L Diesel Engine and Johnson Matthey Catalyst at 7/8 Load, 2200 rpm

Table 35 presents the data for the Deutz F6L 714 diesel engine and the Johnson Matthey catalyst under steady state conditions. The soluble organic fraction was 13.4 mg/m^3. The extracts were tested with tester strains TA98 with and without metabolic activation, TA98NR and TA98/1,8DNP$_6$ without S-9 only.

The total mutagenicity was 13,021 and 3,625 for TA98 without and with S-9 respectively. TA98NR without metabolic activity had a total mutagenicity of 3,759 revertants/m^3 raw exhaust. TA98/1,8DNP$_6$ without metabolic activity had a value of 940 revertants/m^3 of raw exhaust.

8.3.6 Evaluation of a Johnson Matthey Exhaust Purifier for Particulate and Gaseous Emission

Description

Two Johnson Matthey exhaust purifiers were installed on the cylinder head exhaust flanges of a Deutz F6L 714 diesel engine. These devices, supplied by Engine Control Systems, contain a compressed mesh material which has been coated with a catalyst. Installation of the purifiers required removal of the standard exhaust manifold. Thermocouples were used to measure exhaust temperatures and two 'U'-tube water manometers were used to measure the differential exhaust pressure across the purifiers. Engine fuel consumption was determined by weighing the amount of fuel consumed over a known period of time.

The physical configuration of the purifiers installed on the test engine required baseline emission tests to be conducted without the control devices installed. Results presented for the baseline tests are true engine baseline conditions without the purifiers and are not pre-purifier results. It is assumed, however, that differences between baseline and pre-purifier results are negligible.

Table 36 is a summary of the particulate data for the Deutz F6L 714 diesel engine at different rpm and loads. Table 37 presents a summary of particulate data for the Deutz F6L 714 diesel engine equipped with a Johnson Matthey catalyst.

ORI

Gaseous concentrations for baseline and purifier tests are summarized in Table 39. The CO_2 concentrations are approximately 10% for the purifier tests and is reflected in the O_2 concentrations. This characteristic may be due to the partial oxidation of combustible species collected on the purifier substrate. Exhaust flows were, therefore, calculated from the baseline emissions data and assumed to be identical for purifier tests at the same load/speed conditions.

The purifier reduced CO concentrations by up to 99.5% at the rated engine condition. Carbon monoxide oxidation efficiency decreased to 96.7% at the 1900 rpm, 72 and 48 kW load conditions. Total hydrocarbons (expressed as equivalent methane) were removed by up to 93.5% with the purifier. The removal efficiency decreased to a low of 88.7% at the 1900 rpm, 72 kW condition.

Table 39 gives the concentrations of NO_2 for baseline and purifier tests. The purifier appears to remove all the NO_2 present (10 ppm) at two of the full load conditions tested. However, at the intermediate loads the purifier converts NO to NO_2. The percent increases are 260 and 234 for 2200 rpm and 78 and 53 kW respectively. Post-purifier NO_2 concentrations were 122 and 102 ppm for 1900 rpm at 72 and 48 kW respectively.

Table 40 gives baseline carbon monoxide concentrations and emission rates, while Table 41 gives concentrations and emission rates for the post-purifier tests. Baseline total hydrocarbon (expressed as CH_4) concentrations and emission rates are presented in Table 42 and post-purifier results are given in Table 43. Oxides of nitrogen results are given in Tables 44 and 45 for baseline and post-purifier tests, respectively.

Baseline SO_2 and $SO_4^=$ results are shown in Table 46. Duplicate tests were performed at four load/speed conditions with excellent reproducibility with the exception of the 26 ppm value at 1900 rpm and 96 kW. This result is suspected to be spurious; however, the subsequent test results

41 ppm) appears to be correct. Results for the 1900 rpm, 72 and 48 kW load/speeds were calculated based on a fuel sulphur content of 0.108% $(^{w}/w)$. Sulphate concentrations were low for the baseline tests. Table 47 gives SO_2 and $SO_4^{=}$ results for the purifier tests. It can be seen that the SO_2 concentrations are quite low, whereas the $SO_4^{=}$ concentrations increased significantly when compared to baseline data. Again, there is good SO_2 concentration reproducibility for the duplicate tests. The sulphate concentrations (2.8 and 23 ppm) for the 2200, 78 kW tests are noticeably different. It is assumed that the purifier may have stored and subsequently released $SO_4^{=}$ during testing under these conditions. The spread in $SO_4^{=}$ duplicate test data for the remaining load/speed tests is negligible. The purifier appears to be storing sulphates at all load/speeds tested.

9. CONCLUSIONS

With the exception of the Detroit Diesel engine, all engines and catalysts showed a positive mutagenic response to the *Salmonella* tester strain TA98 without metabolic activation.

In all cases where samples were tested in the presence of metabolic activation there was a reduction in the level of mutagenic activity expressed indicating the possibility of deactivation. Some known mutagen/carcinogens, *e.g.*, benzo(a)pyrene, require metabolic activation for the expression of their mutagenicity.

In all cases where samples were tested with the nitroreductase deficient TA98 tester strain without metabolic activation, the level of mutgenicity expressed was lower than the level of mutagenicity for TA98 without metabolic activation.

These observations support the hypothesis that nitroarenes or nitrated polyaromatic hydrocarbons are present in the soluble organic fraction from whole diesel particulates under all conditions tested.

ORI

Total direct-acting mutagenicity appears to be composed of several classes of components, i.e., nitroreductase active, dinitroreductase active and non-nitroreductase active components.

In general, there is close agreement with the parallel study conducted by Dr. Westaway's group from Laurentian University for samples collected in the underground environment. Considering the complexity of the methodologies, the results indicate good reproducibility for replicate samples when expressed in terms of revertants per cubic metre of undiluted exhaust. This provides solid values on which to base a comparison with the massive U.S. light duty diesel cancer risk assessment programme.

Literature shows sampling artifacts can be created by the reactions of NO_2 on particulates. However, it is our opinion that samples collected at a 16:1 dilution ratio are representative of mutagen levels present in an operating mine condition.

Mutagenicity test results obtained for particulate sample stored at $-80^{\circ}C$ on an unextracted filter for six months gave reproducible data confirming these storage conditions do not produce any significant artifacts.

Exhaust samples collected from diesel engines operating at steady state (worst case) conditions can be ranked according to their mutagenic activities as follows:

(i) Detroit Diesel DDAD 8V71N exhibits no detectable mutagenic activity. This result confirms two previous tests conducted for Detroit Diesel engines.

(ii) Deutz F6L 714 diesel engine produced an average of 17,000 revertants/m^3 undiluted exhaust for TA98 without S-9.

(iii) Deutz F6L 912W produced a similar response to that of the Deutz F6L 714, i.e., 28,000 revertants/m^3 undiluted exhaust.

(iv) Caterpillar 3304NA diesel engine produced the highest mutagenic response for a raw engine, i.e., 58,000 revertants/m^3 undiluted exhaust.

Testing of the Deutz F6L 714 diesel engine at 1600 rpm, full load, resulted in lower levels of mutagenic activity than those produced at steady state, i.e., 3,000 revertants/m^3 undiluted exhaust.

LHD cycle testing, using Inco hot cycle and Deutz F6L 912W diesel engine produced results lower than the same engine when operated under steady state conditions, i.e., 16,000 revertants/m^3 undiluted exhaust.

The three catalysts tested were examined at steady state on the Deutz F6L 714 diesel engine.

(i) The Johnson Matthey catalyst showed a reduction of mutagenic activity in comparison to the Deutz F6L 714 untreated exhaust, i.e., 13,000 revertants/m^3 undiluted exhaust. The Johnson Matthey catalyst was only tested once and we suspect it was storing mutagens.

(ii) The PTX catalyst increases the mutagenicity over the Deutz F6L 714 untreated exhaust by approximately a factor of 4, i.e., 76,000 revertants/m^3 undiluted exhaust.

(iii) Of the three catalysts tested, the Dieseler III catalyst was the worst, producing the highest level of potentially harmful materials, i.e., 424,000 revertants/m^3 undiluted exhaust.

10. RECOMMENDATIONS

From the studies we have conducted on the mutagenicity of diesel exhaust, we recommend the following parameters should be investigated in more detail:

(i) Some indications are that lower filter temperatures (30 - 40°C) may collect more of the mutagenically active components due to condensation and absorption on the particulates or filters. We suspect that at the higher temperatures where most of our samples were collected at between 50 and 54°C, a significant amount of the components may pass through the filters in a gaseous phase.

(ii) Experiments should be conducted to determine the level of NO_2 and NO_x required to generate significant artifacts during the collection process.

(iii) Certain types of exhaust treatment devices such as catalysts and exhaust filters, appear to store mutagenic material under steady state conditions. These devices should be tested over LHD cycle conditions to ensure the change in total mutagenicity is real and not due to storage and subsequent release.

A. J. Horton

A.J. Horton
Senior Technologist

N. S. Belson

N.S. Belson
Assistant Research Scientist

H. Wergeer
Senior Technologist

DK Smith

D.K. Smith
Assistant Director

A. Lawson, Ph.D.
Manager, Centre for Alternate Fuel Utilization

Environmental & Chemical
Engineering Division

Engineering Sciences Division

REFERENCES

1. LAWSON, A., D.K. Smith, H. Vergeer, A.J. Horton, W.A. Drummond, N. Belson, "A Study of the Sampling and Assay Methodology Necessary to Determine the Mutagenic Potential of Diesel Exhaust Particulates by the Ames Salmonella Bioassay." Final Report ORF 81-1 to CANMET under DSS Contract 1SQ80-00045, March 31st, 1981.

2. WESTAWAY, K.C., "The Quantitative Assessment of Polynuclear Aromatic Hydrocarbon Levels in Uranium Mines" Final Report, CANMET Contract UP-L-98, April, 1980.

3. WESTAWAY, K.C., "Polynuclear Aromatic Hydrocarbon Concentrations in Dieslized Underground Mines." Final Report to CANMET under DSS Contract 01SU. 23440-9-9140, April, 1981.

4. BRADOW, R.L., R.B. Zweidinger, F.M. Black, H.M. Dietzmann, "Sampling Diesel Engine Particle and Artifacts from Nitrogen Oxide Interactions. Diesel Engine Combustion, Emissions and Particulates." International Congress and Exposition P-107, February 22-26, 1982 820182.

5. WESTAWAY, K.C., "Polynuclear Aromatic Hydrocarbon Concentrations in Dieslized Ungerground Mines." Final Report to CANMET under DSS Contract 01SU.23440-9-9140 April, 1981.

6. SCHUETZLE D., F.C.S. Lee, T.J. Prater, S.B. Tejada, "Int. J. Environ. Anal. Chem. 9, 93. 1981.

7. WESTAWAY, K.C., "Polynuclear Aromatic Hydrocarbon Concentrations in Dieslized Ungerground Mines." Final Report to CANMET under DSS Contract 01SU.23440-9-9140 April, 1981.

8. HUNTER, G., J. Scholl, F. Hibbler, S. Bagley, D. Leddy, D. Abata; J. Johnson, "The Effects of fuels on Diesel Oxidation Catalyst Performance and the Physical, Chemical, and Biological Character of Diesel Particulate Emissions." Reprint 1981 SAE Paper.

9. SCHUETZLE, D., T.J. Prater, T. Riley, A. Durisin, I. Salmeen, "Analysis of Nitrated Derivatives of PAH and Determination of Their Contribution to Ames Mutagenicity for Diesel Particulate Extracts." Presented at the Fifth International Symposium on Polynuclear Aromatic Hydrocarbons, Columbus, Ohio, October 28th, 1980.

10. ROSENKRANZ, H.S., Editoral, "Direct-acting Mutagens in Diesel Exhaust: Magnitude of the Problem." Mutation Research 101 1-10.

11. HUISINGH J., L. Claxton et.al., "Application of Bioassay to the Characterization of Diesel Particulate Emissions. In Application of Short- term Bioassays in the Fractionation and Analysis of Complex Mixtures." Plenum Press pages 383-418.

12. CLAXTON, L.D., "Mutagenic and Carcinogenic Potency of Diesel and Related Environmental Emissions: Salmonella Bioassay. In Health Effect of Diesel Engine Emissions": Proceedings of an International Symposium Volume 2 Page 804-805.

13. BROOKS, A., R. Wolff, R. Royer, C. Clark, A. Sanchez, R. McClellan, "Biological Availability of Mutagenic Chemicals Associated with Diesel Exhaust Particles. Health Effects of Diesel Engine Emissions." Proceedings of the International Symposium, U.S. EPA-600/9-80-057, Cincinnati, Ohio.

14. LAWSON, A., D.K. Smith, H. Vergeer, A.J. Horton, W.A. Drummond, N. Belson, "A Study of the Sampling and Assay Methodology Necessary to Determine the Mutagenic Potential of Diesel Exhaust Particulates by the Ames Salmonella Bioassay." Final Report ORF 81-1 to CANMET under DSS Contract 1SQ80-00045, March 31st, 1981.

15. BAGLEY, S.T., Michigan Technological University; Private Communication.

16. AMES, B.N., J. McCann, E. Yamasaki. "Methods for Detecting Carcinogens and Mutagens with the Salmonella/Mammalion Microsome Mutagenicity Test." Mutation Research 31, 347-364. 1975.

17. CLAXTON, L.D., "Mutagenic and Carcinogenic Potency of Diesel and Related Environmental Emissions: Salmonella Bioassay in Health Effect of Diesel Engine Emissions.": Proceedings of an International Symposium. Volume 2 Page 803.

18. PITTS, J.N. Jr., "Geographical and Temporal Distribution of Atmospheric Mutagens in California." Final Report A7-138-30 California Air Resources Board May 1980, PB81-15826.

19. PITTS, J.N. Jr., "Geographical and Temporal Distribution of Atmospheric Mutagens in California." Final Report A7-138-30 California Air Resources Board May 1980, PB81-15826.

20. de SERRES, F.J., M.D. Shelby. "Recommendations on Data Production and Analysis Using the Salmonella/Microsome Mutagenicity Assay." Environmental Mutagenesis 1. 87-92 1979.

21. LAWSON, A., D.K. Smith, H. Vergeer, A.J. Horton, W.A. Drummond, N. Belson, "A Study of the Sampling and Assay Methodology Necessary to Determine the Mutagenic Potential of Diesel Exhaust Particulates by the Ames Salmonella Bioassay." Final Report ORF 81-1 to CANMET under DSS Contract 1SQ80-00045, March 31st, 1981.

ORI

22. MERMELSTEIN, R., D.K. Kiriazides, M. Butler, E.C. McCoy, H.S. Rosenkranz, "The Extraordinary Mutagenicity of Nitropyrenes in Bacteria Mutation Research." 80 187-196, 1981.

23. ROSENKRANZ, H.S., R. Mermelstein, "Mutagenicity and Genotoxicity of Nitroarenes : All Nitro-containing Chemicals were not Created Equal." Mutation Research 114 217-267, 1983.

24. MERMELSTEIN, R., D.K. Kiriazides, M. Butler, E.C. McCoy, H.S. Rosenkranz, "The Extraordinary Mutagenicity of Nitropyrenes in Bacteria Mutation Research." 89 187-196, 1981.

25. MCCOY, E.C., J.E. Rosenkranz, H.S. Rosenkranz, R. Mermelstein, "Nitrated Fluorene Derivatives are Potent Frameshift Mutagens, Mutation Research." 90 11-20, 1981.

26. H.S. ROSENKRANZ, Case Western University Cleveland, Ohio; Private Communication.

ORI

APPENDIX 1

TABLES

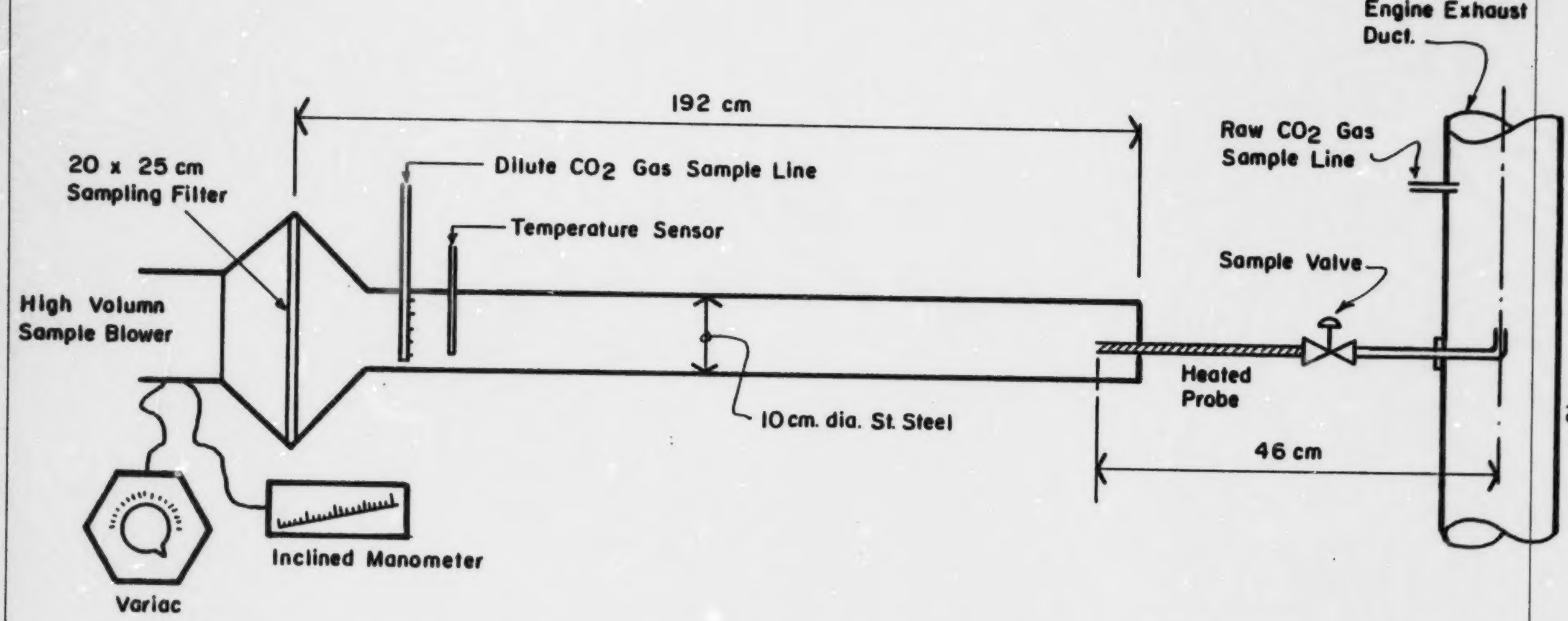
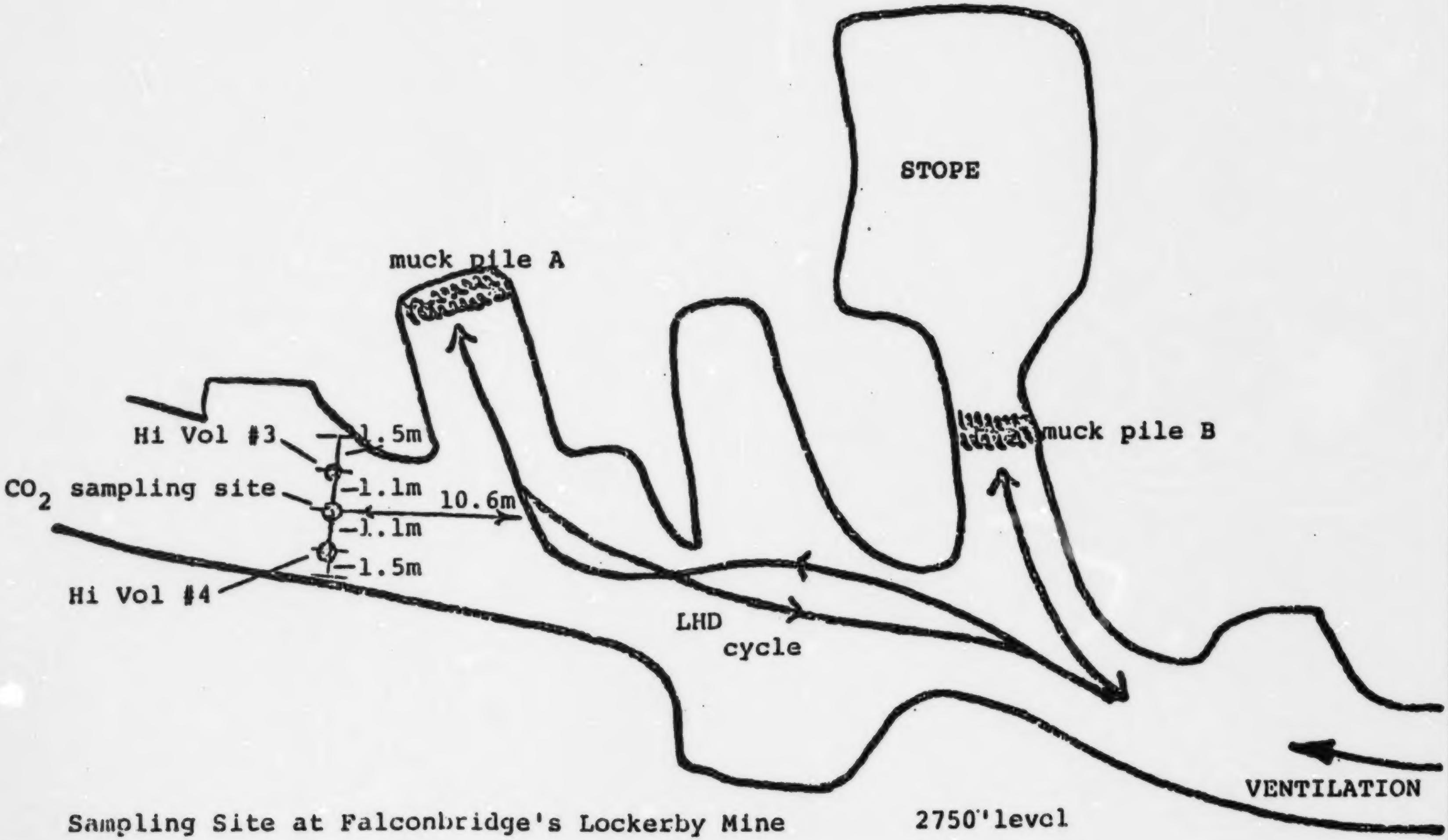

Engine Exhaust Duct.
Raw CO_2 Gas Sample Line
Sample Valve
Heated Probe
46 cm
192 cm
20 x 25 cm Sampling Filter
Dilute CO_2 Gas Sample Line
Temperature Sensor
High Volumn Sample Blower
10 cm. dia. St. Steel
Inclined Manometer
Variac

FIGURE 1. DILUTION TUBE

ORF

Scale 1 cm. = 3.2 m.


STOPE
muck pile A
muck pile B
Hi Vol #3
1.5m
1.1m
CO_2 sampling site
10.6m
1.1m
1.5m
Hi Vol #4
LHD cycle
VENTILATION

Sampling Site at Falconbridge's Lockerby Mine 2750' level

Figure 2

Table 1

Gaseous Components Measured Underground at Falconbridge's Lockerly Mine during Hi Vol Sampling for Mutagenicity Testing

Sampling Period	December 8	December 9	December 10
Ventilation cfm	28,000	28,600	28,000
% Relative Humidity	Not measured	Not measured	61%
Temperature °C	23°C	23.6 ± 0.7°C	23.3 ± 0.1°C
Instantaneous % CO_2	0.10, 0.08	0.14%	0.09%, 0.09%
Time-weighted average % CO_2	0.067%	0.128%	0.072%
NO_x PPM	3	4	6
NO_2 PPM	Not measured	0.1	0.11
CO PPM	3	3	4
SO_2 PPM	Not detected	Not detected	Not detected
CO Right Exhaust Raw Exhaust PPM	50	53	52
CO Left Exhaust Raw Exhaust PPM	40	50	55

Table 2

Summary of the Salmonella Tester Strain Mutations

TA1535 his G46, uvrb, rfa	base-pair substitution (missense) mutation.
TA100 his G46, uvrb, rfa	base-pair substitution missense mutation plus the R-FACTOR pKM101.
TA1537 his C3076, uvrb, rfa	frameshift mutation.
TA1538 his D3052, uvrb, rfa	frameshift mutation.
TA98 his D3052, uvrb, rfa	frameshift mutation plus the R-FACTOR pKM101.
TA98NR his D3052, uvrb, rfa	frameshift mutation plus the R-FACTOR pKM101, minus the classical nitroreductase.
TA98NR/1,8DNP$_6$ his D3052, uvrb, rfa	frameshift mutation plus the R-FACTOR pKM101, minus the nitroreductase that responds to dinitropyrene.
TA98/NR/1,8DNP$_6$ his D3052, uvrb, rfa	frameshift mutation plus the R-FACTOR pKM101, minus both nitroreductase enzymes.

Table 3

Test Conditions Observed during Particulate Sampling for Task 1A

Test No.	Pb Hq (inches)	Temperatures °C					NO_x Concentrations		Hi-Vol ΔP H_2O (inches)	Time min.	Dilution Ratio
		Room	Tube	Right Exhaust	Left Exhaust	In-take Air	Exhaust ppm	Tube ppm			
Non-Catalyst Tests											
1	29.82	26	45	485	496	25	670	50	0.6	25.0	13.4
2	29.83	26	47	487	495	30	670	50	0.6	25.0	13.4
3	29.83	23	47	481	483	30	670	55	0.6	25.0	12.2
4	29.83	24	43	469	475	30	670	50	0.5	25.0	13.4
Avg.			45				670	51			
5	30.25	22	56	463	468	27	670	70	0.5	25.0	9.6
6	30.27	22	59	465	470	27	675	75	0.5	25.0	9.0
7	30.27	23	58	474	479	27	710	80	0.5	25.0	8.9
8	30.28	24	58	478	482	27	695	80	0.5	25.0	8.7
9	30.29	24	58	476	480	27	700	80	0.5	25.0	8.8
Avg.			58				690	77			9.0

Continued .....

Table 3 (continued)

Test Conditions Observed during Particulate Sampling for Task 1A

Test No.	Pb Hq (inches)	Temperature °C					NO_x Concentrations		Hi-Vol ΔP H_2O (inches)	Time min.	Dilution Ratio
		Room	Tube	Right Exhaust	Left Exhaust	In-take Air	Exhaust ppm	Tube ppm			
Catalyst Tests											
10	30.00	22	51	481	472	24	630	65	0.6	15.0	9.7
11	30.00	23	42	482	471	23	640	50	0.6	23.0	12.8
12	30.00	23	41	483	473	25	615	45	0.6	25.0	13.7
13	30.00	23	42	486	476	25	610	50	0.6	25.0	12.2
14	30.00	23	43	490	478	23	605	40	0.6	25.0	15.1
15	29.99	24	42	488	473	26	605	40	0.6	25.0	15.1
16	30.12	23	44	491	485	30	620	48	0.6	23.5	12.9
17	30.14	24	43	493	480	29	620	47	0.6	22.0	13.2
18	30.15	24	43	491	485	30	615	45	0.6	25.0	13.7
19	30.18	26	44	489	479	29	620	46	0.6	17.5	13.5
20	30.20	23	42	493	484	32	615	45	0.6	17.0	13.7
Avg.			43				618	47			13.1

Date	Test No.	Dilution Ratio	Dilution Tube Gas Temp. °C	Total Volume m³	Total Particulate mg	Soluble Particulate mg	Insoluble Particulate mg	Engine Particulate Concentrations			Soluble % of Total
								Soluble mg/m³	Insoluble mg/m³	Total** mg/m³	
Non-Catalyst Tests											
19.01.82	1	13.4	45	25.7	83.3	27.4	55.9	14.3	29.1	43.4	32.9
	2	13.4	47	25.8	86.4	25.6	60.8	13.3	31.6	44.9	29.6
	3	12.2	47	25.8	90.3	27.3	63.0	12.9	29.8	42.7	30.2
	4	13.4	43	25.6	97.2	34.8	62.4	18.2	32.7	50.9	35.8
Average		13.1	45					14.7	30.8	45.5	32.3
21.01.82	5	9.6	56	23.6	115.5	37.8	77.1	15.4	31.4	46.8	32.9
	6	9.0	59	23.6	114.0	38.2	75.8	14.6	28.9	43.5	33.6
	7	8.9	58	23.6	103.5	36.3	67.2	13.7	25.3	39.0	35.1
	8	8.7	58	23.6	103.3	31.8	71.5	11.7	26.4	38.1	30.7
	9	8.8	58	23.6	96.7	29.1	67.6	10.9	25.2	36.1	30.3
Average		9.0	58					13.3	27.4	40.7	32.7
Catalyst Tests											
26.01.82	10	9.7	51	14.5	45.1	7.8	37.3	5.2	25.0	30.2	17.2
	11	12.8	42	23.5	44.6	8.1	36.5	4.4	19.9	24.3	18.1
	12*	13.7	41	25.5	41.6	18.5	23.1	9.9	12.4	22.3	44.4
	13	12.2	42	25.5	44.7	10.0	34.7	4.8	16.6	21.4	22.4
	14	15.1	43	25.6	44.8	9.9	34.9	5.8	20.6	26.4	22.0
	15	15.1	42	25.6	58.9	10.7	48.2	6.3	28.4	34.7	18.2
	16	12.9	44	23.9	51.2	12.5	38.7	6.7	20.9	27.6	24.3
	17	13.2	43	22.7	40.7	12.9	27.8	7.5	16.2	23.7	31.6
	18*	13.7	43	25.5	80.8	9.7	71.1	5.2	38.2	43.4	12.0
	19	13.5	44	17.9	33.0	6.8	26.2	5.1	19.8	24.9	20.5
	20	13.7	42	16.8	30.0	6.9	23.1	5.6	18.8	24.4	23.0
Average		13.1	44					5.7	20.7	26.4	21.9

* Values deleted in averaging

** Excluding sulphates

ORF

Date	Test No.	Dilution Ratio	Dilution Tube Gas Temp. °C	Total Volume m³	Total Particulate mg	Soluble Particulate mg	Insoluble Particulate mg	Engine Particulate Concentrations			Soluble % of Total
								Soluble mg/m³	Insoluble mg/m³	Total** mg/m³	
Non-Catalyst Tests											
19.01.82	1	13.4	45	25.7	83.3	27.4	55.9	14.3	29.1	43.4	32.9
	2	13.4	47	25.8	86.4	25.6	60.8	13.3	31.6	44.9	29.6
	3	12.2	47	25.8	90.3	27.3	63.0	12.9	29.8	42.7	30.2
	4	13.4	43	25.6	97.2	34.8	62.4	18.2	32.7	50.9	35.8
Average		13.1	45					14.7	30.8	45.5	32.3
21.01.82	5	9.6	56	23.6	115.5	37.8	77.1	15.4	31.4	46.8	32.9
	6	9.0	59	23.6	114.0	38.2	75.8	14.6	28.9	43.5	33.6
	7	8.9	58	23.6	103.5	36.3	67.2	13.7	25.3	39.0	35.1
	8	8.7	58	23.6	103.3	31.8	71.5	11.7	26.4	38.1	30.7
	9	8.8	58	23.6	96.7	29.1	67.6	10.9	25.2	36.1	30.3
Average		9.0	58					13.3	27.4	40.7	32.7
Catalyst Tests											
26.01.82	10	9.7	51	14.5	45.1	7.8	37.3	5.2	25.0	30.2	17.2
	11	12.8	42	23.5	44.6	8.1	36.5	4.4	19.9	24.3	18.1
	12*	13.7	41	25.5	41.6	18.5	23.1	9.9	12.4	22.3	44.4
	13	12.2	42	25.5	44.7	10.0	34.7	4.8	16.6	21.4	22.4
	14	15.1	43	25.6	44.8	9.9	34.9	5.8	20.6	26.4	22.0
	15	15.1	42	25.6	58.9	10.7	48.2	6.3	28.4	34.7	18.2
	16	12.9	44	23.9	51.2	12.5	38.7	6.7	20.9	27.6	24.3
	17	13.2	43	22.7	40.7	12.9	27.8	7.5	16.2	23.7	31.6
	18*	13.7	43	25.5	80.8	9.7	71.1	5.2	38.2	43.4	12.0
	19	13.5	44	17.9	33.0	6.8	26.2	5.1	19.8	24.9	20.5
	20	13.7	42	16.8	30.0	6.9	23.1	5.6	18.8	24.4	23.0
Average		13.1	44					5.7	20.7	26.4	21.9

EVALUATION OF RAW DATA FROM TABLE 5A

Deutz F6L 714 Engine at 7/8 Load, 2200 rpm

Soluble Organic Fraction	70.3 mg
Sampling Time	120 minutes
Volume	68m^3
Dilution Ratio	16:1
Collection Temperature	50°C
Milligrams per cubic metre (mg/m3)	16.5

Specific Activity	(Revertants/µg)
TA98 w/o S-9	1.598
TA98 w/ S-9	ND
TA98NR w/o S-9	0.475
TA98/1,8DNP$_6$ w/o S-9	0.10
TA98/NR/1,8DNP$_6$ w/o S-9	0.095

Total Mutagenicity	Revertants/m^3 Undiluted Exhaust
TA98 w/o S-9	26,432
TA98 w/ S-9	ND
TA98NR w/o S-9	7857
TA98/1,8DNP$_6$ w/o S-9	1654
TA98/NR/1,8DNP$_6$ w/o S-9	1571

ND = Not Done

ORF

TABLE 5

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine at 7/8 Load,2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	429 437 453	440	412 ± 12	124 117 103	115	86 ± 11
900	320 280 408	336	308 ± 65	122 66 98	95	66 ± 28
800	427 355 405	396	368 ± 37	114 120 159	131	102 ± 24
700	381 456 298	378	350 ± 79	144 151 147	147	118 ± 4
600	370 313 366	350	322 ± 32	124 131 132	125	96 ± 4
500	367 453 338	386	358 ± 60	162 165 151	159	130 ± 7
400	336 290 388	336	308 ± 49	155 171 145	157	128 ± 13
300	365 390 294	350	322 ± 50	133 134 124	150	101 ± 6
200	294 307 274	292	264 ± 17	152 137 117	135	106 ± 18
100	205 217 157	193	165 ± 32	75 103 87	88	59 ± 14
90	57 81 77	72	44 ± 13	14 15 9	13	0 ± 3
80	61 77 75	71	43 ± 9	0 54 45	33	4 ± 29
70	90 85 70	82	54 ± 10	16 23 30	23	0 ± 7
60	82 84 82	83	55 ± 1	37 42 17	32	3 ± 13
50	56 54 89	66	38 ± 20	37 25 39	34	5 ± 8
Controls:						
Negative	20 27 27 26 41	28		20 28 36 26 23	29	
Positive	516 513 382	470		97 105 94	99	
Specific Activity	1.598			0.475		

TABLE 5 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain							
	TA98/1,8DNP$_6$ w/o S-9				TA98/NR/1,8DNP$_6$ w/o S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1000	43	66	55	43 ± 16	39	39	39	0 ± 0
900	86	58	72	60 ± 20	30	51	41	0 ± 15
800	109	61	85	73 ± 34	37	41	39	0 ± 3
700	41	72	57	45 ± 22	31	34	33	0 ± 2
600	46	92	69	57 ± 33	44	42	43	1 ± 1
500	73	99	86	74 ± 18	54	34	44	2 ± 14
400	92	81	87	75 ± 8	48	28	38	0 ± 14
300	82	104	93	81 ± 16	32	26	29	0 ± 4
200	93	81	87	75 ± 9	24	28	26	0 ± 3
100	77	69	73	61 ± 6	22	31	27	0 ± 6
90	53	50	52	40 ± 2	10	22	16	0 ± 9
80	52	44	48	35 ± 6	14	10	12	0 ± 3
70	55	40	48	36 ± 11	19	16	18	0 ± 2
60	43	42	43	31 ± 1	17	18	18	0 ± 1
50	55	88	72	60 ± 23	24	14	19	0 ± 7
Controls:								
Negative	16 6 14 8 16		12		33 49 35 42 53		42	
Positive	29 52 45		42		145 137 159		147	
Specific Activity	0.10				0.095			

EVALUATION OF RAW DATA FROM TABLE 6A

Deutz F6L 714 Engine at 7/8 Load, 2200 rpm

Soluble Organic Fraction	51.5 mg
Sampling Time	120 minutes
Volume	68m^3
Dilution Ratio	16:1
Collection Temperature	50^{0}C
Milligrams per cubic metre (mg/m3)	12.1

Specific Activity	(Revertants/μg)
TA98 w/o S-9	0.975
TA98 w/ S-9	ND
TA98NR w/o S-9	0.58
TA98/1,8DNP$_6$ w/o S-9	0.22
TA98/NR/1,8DNP$_6$ w/o S-9	0.06

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	11,796
TA98 w/ S-9	ND
TA98NR w/o S-9	7029
TA98/1,8DNP$_6$ w/o S-9	2666
TA98/NR/1,8DNP$_6$ w/o S-9	727

ND = Not Done

TABLE 6

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain							
	TA98 w/o S-9				TA98NR w/o S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1000	307	285	296	248 ± 16	99	143	121	91 ± 31
900	209	285	247	199 ± 54	107	121	114	84 ± 10
800	323	222	273	225 ± 71	115	115	115	85 ± 0
700	294	321	308	260 ± 19	115	114	115	85 ± 1
600	373	343	358	310 ± 21	154	135	145	115 ± 3
500	322	287	305	257 ± 25	112	104	108	78 ± 6
400	313	332	323	275 ± 13	150	135	143	113 ± 11
300	318	308	313	265 ± 7	136	135	136	106 ± 1
200	290	264	277	225 ± 18	127	125	126	96 ± 1
100	171	178	175	127 ± 5	79	88	84	54 ± 6
90	81	87	84	36 ± 4	42	33	38	8 ± 6
80	113	112	113	65 ± 1	38	52	45	15 ± 10
70	106	102	104	56 ± 3	51	48	50	20 ± 2
60	96	99	98	50 ± 2	57	49	53	23 ± 6
50	86	116	101	53 ± 21	48	33	41	11 ± 11
Controls:								
Negative	42 48 56 59 36		48		35 28 29 36 24		30	
Positive	309 533 332		391		100 86 126		104	
Specific Activity	0.975				0.58			

ORF

TABLE 6 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98/1,8DNP$_6$ w/o S-9			TA98/NR/1,8DNP$_6$ w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	59 27	43	25 ± 23	61 64	63	19 ± 2
900	47 43	45	27 ± 3	62 78	70	26 ± 11
800	60 37	49	31 ± 16	65 78	72	28 ± 9
700	88 94	91	73 ± 4	79 86	83	39 ± 5
600	82 75	79	61 ± 5	86 77	82	38 ± 6
500	58 71	65	47 ± 9	67 63	65	21 ± 3
400	53 45	49	31 ± 6	55 65	60	16 ± 7
300	96 67	82	64 ± 21	53 67	60	16 ± 10
200	46 45	46	28 ± 1	53 53	53	9 ± 0
100	29 29	29	11 ± 0	32 40	36	0 ± 6
90	17 14	16	0 ± 2	24 32	28	0 ± 6
80	37 31	34	16 ± 4	42 48	45	1 ± 4
70	23 20	22	4 ± 2	47 29	38	0 ± 13
60	22 28	25	7 ± 4	32 37	35	0 ± 4
50	29 27	28	10 ± 1	34 46	40	0 ± 9
Controls:						
Negative	14 14 33 13 17	18		50 49 32 36 52	44	
Positive	67 62 60	63		154 192 134	160	
Specific Activity	0.22			0.06		

EVALUATION OF RAW DATA FROM TABLE 7A

Deutz F6L 714 Engine at 7/8 Load, 2200 rpm

Soluble Organic Fraction	17.4 mg
Sampling Time	30 minutes
Volume	17m^3
Dilution Ratio	16:1
Collection Temperature	50^{0}C
Milligrams per cubic metre (mg/m3)	16.4

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.891
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	14,591
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

ORF

TABLE 7

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine @ 7/8 Load,2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain		
	TA98 w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	406	406	378
900	383 374 391	383	355 ± 9
800	461 375 480	439	411 ± 56
700	416 483 491	463	435 ± 41
600	436 441 430	436	408 ± 6
500	446 419 383	416	388 ± 32
400	417 431 400	416	388 ± 16
300	367 359 366	364	336 ± 4
200	279 278 325	294	266 ± 27
100	183 190 184	186	158 ± 4
90	88 92 83	88	60 ± 5
80	73 77 61	70	42 ± 8
70	73 71 67	70	42 ± 3
60	76 85 65	75	47 ± 10
50	69 73 80	74	46 ± 6
Controls:			
Negative	20 27 27 26 41	28	
Positive	516 513 382	470	
Specific Activity	0.891		

ORI

EVALUATION OF RAW DATA FROM TABLE 8A

Deutz F6L 714 Engine at 7/8 Load, 2200 rpm

Soluble Organic Fraction	61 mg
Sampling Time	30 minutes
Volume	17m^3
Dilution Ratio	16:1
Collection Temperature	50^{o}C
Milligrams per cubic metre (mg/m3)	57.4

Specific Activity	(Revertants/μg)
TA98 w/o S-9	0.303
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	17,392
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 8

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L Engine at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain				
	TA98 w/o S-9				
	Histidine Revertants			Average	Net Revertants ± Standard Deviation
1000	176	183	166	175	147 ± 9
900	151	173	201	175	147 ± 25
800	169	226	190	195	167 ± 29
700	182	143	186	170	142 ± 24
600	178	186	141	168	140 ± 24
500	158	169	174	167	139 ± 8
400	151	175	152	159	131 ± 14
300	139	134	140	138	110 ± 3
200	126	107	97	110	82 ± 15
100	85	103	89	92	64 ± 10
90	39	44	47	43	15 ± 4
80	44	46	46	45	17 ± 1
70	39	46	50	45	17 ± 6
60	40	41	35	39	11 ± 3
50	43	47	59	50	22 ± 8
Controls:					
Negative	20 27	27 26	41	28	
Positive	516	513	382	470	
Specific Activity	0.303				

ORF

EVALUATION OF RAW DATA FROM TABLE 9A

Deutz F6L 912 W Engine at 7/8 Load, 2200 rpm, Vent Fan Low

Soluble Organic Fraction	29.7 mg
Sampling Time	
Volume	$25.7m^3$
Dilution Ratio	32:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	37.0

Specific Activity	(Revertants/ug)
TA98 w/o S-9	0.72
TA98 w/ S-9	ND
TA98NR w/o S-9	0.33
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	26,626
TA98 w/ S-9	ND
TA98NR w/o S-9	12,204
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

8% CO_2

ND = Not Done

TABLE 9

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz FL912 W Engine at 7/8 Load, 2200 rpm, Vent Fan Low

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
800	218 180 161 sl.tox.	186	157 ± 29	166 147 126	146	130 ± 20
600	197 171 248	205	176 ± 39	136 106 150	131	115 ± 23
500	207 200 195	201	172 ± 6	113 103 134	117	101 ± 16
400	211 210 211	211	182 ± 1	110 121 121	117	101 ± 6
350	208 204 184	199	170 ± 13	90 119 110	106	90 ± 15
300	212 223 211	215	186 ± 7	118 130 109	119	103 ± 11
250	173 201 212	195	166 ± 20	87 101 115	101	85 ± 14
200	204 211 224	213	184 ± 10	77 98 108	94	78 ± 16
150	149 156 127	144	115 ± 15	77 93 89	86	70 ± 8
100	102 110 96	103	74 ± 7	56 79 76	70	54 ± 13
80	48 47 54	50	21 ± 4	40 50 40	43	27 ± 6
60	46 52 71	56	27 ± 13	57 52 36	48	32 + 11
40	35 66 46	49	20 ± 16	37 33 29	33	17 ± 4
20	54 46 36	45	16 ± 9	19 27 29	25	9 ± 5
Controls:						
Negative	33 24 35 28 26	29		11 14 11 28 15	16	
Positive	368 501 644	504		81 72 86	80	
Specific Activity	0.72			0.33		

EVALUATION OF RAW DATA FROM TABLE 10A

Deutz F6L 912 W Engine at 7/8 Load, 2200 rpm, Vent Fan High

Soluble Organic Fraction	35.4 mg
Sampling Time	
Volume	48.9m^3
Dilution Ratio	76:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	55.0

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.51
TA98 w/ S-9	ND
TA98NR w/o S-9	Negative
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m³ Undiluted Exhaust)
TA98 w/o S-9	28,059
TA98 w/ S-9	ND
TA98NR w/o S-9	Negative Mutagenic Response
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

8% CO_2

ND = Not Done

TABLE 10

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz FL912 W Engine at 7/8 Load, 2200 rpm, Vent Fan High

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
800	127 119 117 Sl. Tox.	121	78 ± 5	58 63 84 Sl. Tox.	68	42 ± 14
600	162 92 110 Sl. Tox.	121	78 ± 36	61 67 71 Sl. Tox.	66	40 ± 5
500	146 124 119	130	87 ± 14	57 75 58	63	37 ± 10
400	130 143 112	128	85 ± 16	56 63 76	65	39 ± 10
350	124 114 139	126	83 ± 13	56 65 36	52	26 ± 15
300	123 184 147	151	108 ± 31	61 77 63	67	41 ± 9
250	145 107 132	128	85 ± 19	92 68 57	72	46 ± 18
200	134 136 129	133	90 ± 4	77 86 81	81	55 ± 5
150	102 118 143	121	78 ± 21	46 60 64	57	31 ± 10
100	122 121 94	112	69 ± 16	60 71 55	62	36 ± 8
80	46 40 46	44	1 ± 3	28 30 24	27	1 ± 3
60	46 59 45	50	7 ± 8	35 17 36	29	3 ± 11
40	72 60 63	65	22 ± 6	17 19 19	18	0 ± 1
20	52 57 56	55	12 ± 3	28 23 29	27	1 ± 3
Controls:						
Negative	49 38 48 35 47	43		27 29 28 19 26	26	
Positive	306 278 385	323		100 109 88	99	
Specific Activity	0.51			Negative		

EVALUATION OF RAW DATA FROM TABLE 11A

Caterpillar 3304 Engine at 7/8 load, 2200 rpm

Soluble Organic Fraction	101 mg
Sampling Time	
Volume	100.63m^3
Dilution Ratio	34.4:1
Collection Temperature	
Milligrams per cubic metre (mg/m^3)	34.53

Specific Activity	(Revertants/μg)
TA98 w/o S-9	1.35
TA98 w/ S-9	ND
TA98NR w/o S-9	0.81
TA98/1,8DNP$_6$ w/o S-9	Negative
TA98/NR/1,8DNP$_6$ w/o S-9	Negative

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	46,611
TA98 w/ S-9	ND
TA98NR w/o S-9	27,966
TA98/1,8DNP$_6$ w/o S-9	Negative Mutagenicity
TA98/NR/1,8DNP$_6$ w/o S-9	Negative Mutagenicity

ND = Not Done

TABLE 11

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Caterpillar 3304 Engine at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	615 528 655 sl.tox.	549	498 ± 65	169 79 79 sl.tox.	109	71 ± 52
800	449 557 574 sl.tox.	527	476 ± 68	176 136 123 sl.tox.	117	79 ± 28
600	362 430 346 sl.tox.	379	328 ± 45	125 135 118	126	88 ± 9
500	469 453 416	446	395 ± 27	139 154 129	141	103 ± 13
400	454 448 364	422	371 ± 50	182 193 155	177	139 ± 20
350	449 369 303	374	323 ± 73	94 130 119	114	76 ± 18
300	490 425 448	454	403 ± 33	91 145 191	142	104 ± 50
250	466 352 363	394	343 ± 63	162 93 184	146	108 ± 47
200	376 430 345	384	333 ± 43	166 201 147	171	133 ± 27
150	336 308 304	316	265 ± 17	185 165 136	162	124 ± 25
100	287 352 349	329	278 ± 37	142 155 150	149	111 ± 7
80	162 168 146	159	108 ± 11	20 36 15	24	0 ± 11
60	148 112 113	124	73 ± 21	38 14 34	29	0 ± 13
40	100 113 124	112	61 ± 12	45 82 50	59	21 ± 20
20	77 80 100	86	35 ± 13	58 41 78	59	21 ± 19
Controls:						
Negative	53 49 63 43 49	51		17 30 46 38 58	38	
Positive	480 635 474	530		135 155 154	148	
Specific Activity	1.35			0.81		

TABLE 11 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Caterpillar 3304 Engine at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98/1,8DNP$_6$ w/o S-9			TA98/NR/1,8DNP$_6$ w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	25 41 24 sl.tox.	30	13 ± 10	4 7 4 sl.tox.	5	0 ± 2
800	23 58 55	45	28 ± 19	7 16 6 sl.tox.	10	4 ± 6
600	24 37 55	39	22 ± 16	9 16 3 sl.tox.	9	3 ± 7
500	25 53 56	45	28 ± 17	10 8 8	9	3 ± 1
400	27 27 66	40	23 ± 23	7 6 9	7	1 ± 2
350	10 24 33	22	5 ± 12	11 10 5	9	3 ± 3
300	46 47 41	45	28 ± 3	2 3 3	3	0 ± 1
250	45 21 23	30	13 ± 13	3 10 18	10	4 ± 8
200	39 57 51	49	32 ± 9	39 15 11	22	16 ± 15
150	34 39 36	36	19 ± 3	18 20 27	22	16 ± 5
100	26 43 47	39	22 ± 11	27 13 23	21	15 ± 7
80	12 14 20	15	0 ± 4	8 8 7	8	2 ± 1
60	22 28 24	25	8 ± 3	7 9 11	9	3 ± 2
40	32 20 25	26	9 ± 6	5 5 11	7	1 ± 3
20	21 26 29	25	8 ± 4	2 5 2	3	0 ± 2
Controls:						
Negative	24 15 19 13 13	17		3 5 9 7 4	6	
Positive	138 153 112	134		22 23 18	21	
Specific Activity	Negative			Negative		

EVALUATION OF RAW DATA FROM TABLE 12A

Caterpillar (stored) 3304 Engine at 7/8 load, 2200 rpm

Soluble Organic Fraction	36.3 mg
Sampling Time	
Volume	22.54m^3
Dilution Ratio	34.4:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	55.4

Specific Activity	(Revertants/µg)
TA98 w/o S-9	1.24
TA98 w/ S-9	ND
TA98NR w/o S-9	0.60
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	68,696
TA98 w/ S-9	ND
TA98NR w/o S-9	33,240
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 12

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Caterpillar 3304 Engine at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	492 557 494 sl.tox.	514	479 ± 37	370 316 308	331	309 ± 34
800	463 504 444	470	435 ± 31	352 320 205	292	270 ± 77
600	454 418 534	469	434 ± 42	247 305 276	276	254 ± 29
500	441 404 427	424	389 ± 19	260 223 227	237	215 ± 20
400	396 383 379	386	351 ± 9	184 178 197	186	164 ± 10
350	329 333 278	313	278 ± 31	161 141 138	147	125 ± 13
300	388 397 404	396	361 ± 8	155 170 217	181	159 ± 32
250	299 340 378	339	304 ± 40	154 146 151	150	128 ± 4
200	318 371 335	341	306 ± 27	176 180 171	176	154 ± 6
150	273 298 274	282	247 ± 14	123 130 156	136	114 ± 17
100	245 251 263	253	218 ± 9	106 122 108	112	90 ± 9
80	144 117 105	122	87 ± 20	45 37 50	44	22 ± 7
60	91 97 128	105	70 ± 20	48 35 33	39	17 ± 8
40	88 89 77	85	50 ± 7	39 42 39	40	18 ± 2
20	64 58 58	60	25 ± 3	31 30 23	28	6 ± 4
Controls:						
Negative	27 33 44 28 42	35		15 19 24 24 26	22	
Positive	421 295 421	379		91 84 67	81	
Specific Activity	1.24			0.60		

ORF

EVALUATION OF RAW DATA FROM TABLE 13A

Detroit Diesel DDAD 8V 71N Engine at 7/8 Load, 2100 rpm

Soluble Organic Fraction	168.4 mg 185.6 mg/loading
Sampling Time	240 minutes
Volume	136m^3
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	19.81

Specific Activity	(Revertants/μg)
TA98 w/o S-9	Negative
TA98 w/ S-9	Negative
TA98NR w/o S-9	Negative
TA98/1,8DNP$_6$ w/o S-9	Negative
TA98/NR/1,8DNP$_6$ w/o S-9	Negative

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	Negative Mutagenicity
TA98 w/ S-9	Negative Mutagenicity
TA98NR w/o S-9	Negative Mutagenicity
TA98/1,8DNP$_6$ w/o S-9	Negative Mutagenicity
TA98/NR/1,8DNP$_6$ w/o S-9	Negative Mutagenicity

CO_2	4.57
O_2	14.6
THC	90 ppm
CO	270 ppm
NO_x	1112 ppm
NO	1038 ppm
NO_2	74 ppm

ND = Not Done

ORI

TABLE 13

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Detroit Diesel DDAD 8V 71N Engine at 7/8 Load, 2100 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98 w/S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	68 60 89	72	25 ± 15	59 80 82	74	22 ± 13
800	63 52 80	65	18 ± 14	82 74 94	83	31 ± 10
600	88 70 69	76	29 ± 11	71 69 53	64	12 ± 10
500	82 68 79	76	29 ± 7	72 62 66	67	15 ± 5
400	68 81 75	75	28 ± 7	62 72 58	64	12 ± 7
350	60 60 68	63	16 ± 5	35 34 42	37	0 ± 4
300	89 97 91	92	45 ± 4	38 46 29	38	0 ± 9
250	55 46 45	49	2 ± 4	40 47 41	43	0 ± 4
200	64 57 67	63	16 ± 5	36 50 38	41	0 ± 8
150	47 48 41	45	0 ± 4	36 38 28	34	0 ± 5
100	60 52 49	54	7 ± 6	32 30 35	32	0 ± 3
80	42 60 49	50	3 ± 6	29 29 33	30	0 ± 2
40	57 52 42	50	3 ± 5	39 39 29	36	0 ± 6
20	53 60 55	56	9 ± 4	38 53 76	56	4 ± 19
Controls:						
Negative	28 46 56 45 58	47		55 48 63 50 42	52	
Positive	1404 1523 1523	1483		1220 1318 1501	1346	
Specific Activity	Negative			Negative		

ORF

TABLE 13 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Detroit Diesel DDAD 8V 71N Engine at 7/8 Load, 2100 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain								
	TA98NR w/o S-9			TA98/1,8DNP$_6$ w/o S-9			TA98/NR/1,8DNP$_6$		
	Histidine Revertants	Average	Net Revertants $\pm$ Standard Deviation	Histidine Revertants	Average	Net Revertants $\pm$ Standard Deviation	Histidine Revertants	Average	Net Revertants $\pm$ Standard Deviation
1000	36 44 41sl.tox.	40	0 ± 3	22 18 10	17	0 ± 6	22 13 16sl.tox.	17	0 ± 5
800	48 50 42sl.tox.	47	7 ± 4	13 19 24	19	0 ± 6	24 25 21	23	2 ± 2
600	49 47 42sl.tox.	46	6 ± 4	8 14 13	12	0 ± 3	40 32 28	33	12 ± 4
500	52 47 57sl.tox.	52	12 ± 5	17 13 24	18	0 ± 6	20 23 25	23	2 ± 2
400	53 66 50sl.tox.	56	16 ± 9	27 12 13	17	0 ± 8	18 19 19	19	0 ± 1
350	25 21 26sl.tox.	24	0 ± 3	10 5 5	7	0 ± 3	30 18 18	22	1 ± 5
300	29 37 23sl.tox.	30	0 ± 7	10 9 24	14	0 ± 8	20 27 32	26	5 ± 6
250	20 17 33sl.tox.	23	0 ± 9	12 18 12	14	0 ± 4	14 25 25	21	0 ± 6
200	41 33 36	37	0 ± 4	29 9 23	20	0 ± 10	18 24 20	21	0 ± 3
150	33 31 40	35	0 ± 5	18 4 13	12	0 ± 7	18 22 20	20	0 ± 2
100	27 29 46	34	0 ± 10	20 40 28	29	0 ± 10	23 23 18	21	0 ± 3
80	26 32 21	26	0 ± 6	18 11 20	16	0 ± 5	20 27 29	25	4 ± 4
40	26 24 25	25	0 ± 1	21 24 27	24	0 ± 3	29 10 16	18	0 ± 10
20	45 29 31	35	0 ± 9	29 45 41	38	0 ± 8	25 25 19	23	2 ± 2
Controls:									
Negative	43 36 50 35 34	40		46 43 41 33 37	40		23 22 21 14 26	21	
Positive	221 190 253	221		158 135 154	149		64 88 82	78	
Specific Activity	Negative			Negative			Negative		

sl. tox. = Slight toxicity.

EVALUATION OF RAW DATA FROM TABLE 14A

Deutz F6L 714 Engine Raw Exhaust at Full Load, 1600 rpm

Soluble Organic Fraction	39.1 mg
Sampling Time	150 minutes
Volume	85m^3
Dilution Ratio	16:1
Collection Temperature	50^{o}C
Milligrams per cubic metre (mg/m3)	7.3

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.43
TA98 w/ S-9	ND
TA98NR w/o S-9	0.07
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	3165
TA98 w/ S-9	ND
TA98NR w/o S-9	515
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

ORF

TABLE 14

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine Raw Exhaust at Full Load, 1600 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants + Standard Deviation
1000	80 62 80 sl.tox.	74	54 ± 10	64 74 60 sl.tox.	66	46 ± 7
900	47 82 65	65	45 ± 18	71 61 61 sl.tox.	64	44 ± 6
800	51 102 71	75	55 ± 26	83 75 87	82	62 ± 6
700	92 103 59	85	65 ± 23	56 65 56	59	39 ± 6
600	108 85 149	114	94 ± 32	60 67 69	63	43 ± 5
500	113 62 122	99	79 ± 32	70 57 67	65	45 ± 7
400	157 167 158	161	141 ± 6	61 51 59	57	37 ± 5
300	121 107 131	120	100 ± 12	64 63 39	62	42 ± 3
200	135 130 108	124	104 + 14	49 49 57	52	32 ± 5
100	62 77 86	75	55 ± 12	40 27 45	37	17 ± 9
80	20 20 20	20	0 ± 0	30 26 23	26	6 ± 4
60	20 35 22	26	6 ± 8	31 16 20	22	2 ± 6
40	20 29 38	29	9 ± 9	27 27 30	28	8 ± 2
20	25 34 27	29	9 ± 5	21 25 21	22	2 ± 2
10	37 23 21	29	9 ± 9	32 23 21	25	5 ± 6
Controls:						
Negative	19 8 22 27 24	20		13 26 27 15 19	20	
Positive	542 651 726	640		92 76 85	84	
Specific Activity	0.43			0.07		

EVALUATION OF RAW DATA FROM TABLE 15A

Deutz F6L 714 Raw Engine at Full Load, 1600 rpm

Soluble Organic Fraction	42.5 mg
Sampling Time	150 minutes
Volume	$85m^3$
Dilution Ratio	16:1
Collection Temperature	50^oC
Milligrams per cubic metre (mg/m3)	8.0

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.41
TA98 w/ S-9	ND
TA98NR w/o S-9	0.07
$TA98/1,8DNP_6$ w/o S-9	ND
$TA98/NR/1,8DNP_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	3280
TA98 w/ S-9	ND
TA98NR w/o S-9	560
$TA98/1,8DNP_6$ w/o S-9	ND
$TA98/NR/1,8DNP_6$ w/o S-9	ND

ND = Not Done

ORF

TABLE 15

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Raw Engine at Full Load, 1600 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	152 112 96	120	78 ± 29	58 90 82	77	54 ± 17
900	156 163 134	151	109 ± 15	82 58 65	68	45 ± 12
800	154 161 144	153	111 ± 9	87 74 69	77	54 ± 9
700	199 183 188	190	148 ± 8	77 66 85	67	53 ± 10
600	190 194 169	184	142 ± 13	82 53 63	66	43 ± 11
500	192 175 160	176	134 ± 16	78 54 69	67	44 ± 12
400	180 195 210	195	153 ± 15	66 61 73	67	44 ± 6
300	165 176 152	164	122 ± 12	63 50 53	55	32 ± 6
200	135 119 127	127	85 ± 8	54 54 50	53	30 ± 2
100	71 97 76	81	39 ± 14	55 34 41	43	20 ± 11
80	65 63 59	62	20 ± 3	24 24 27	25	2 ± 2
60	67 45 42	51	9 ± 14	19 24 32	25	2 ± 7
40	53 60 52	55	13 ± 4	27 25 17	23	0 ± 11
20	54 38 44	45	3 ± 8	28 16 26	23	0 ± 6
10	40 40 43	41	0 ± 2	20 25 30	25	2 ± 5
Controls:						
Negative	42 42 50 39 35	42		23 23 23 25 22	23	
Positive	697 602 593	631		103 67 85	85	
Specific Activity	0.41			0.07		

EVALUATION OF RAW DATA FROM TABLE 16A

Deutz F6L 714 Raw Exhaust at Full Load, 1600 rpm

Soluble Organic Fraction	17.8 mg
Sampling Time	150 minutes
Volume	85m^3
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	3.3

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.27
TA98 w/ S-9	ND
TA98NR w/o S-9	0.15
TA98/1,8DNP$_6$ w/o S-9	0.07
TA98/NR/1,8DNP$_6$ w/o S-9	0.18

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	904
TA98 w/ S-9	ND
TA98NR w/o S-9	503
TA98/1,8DNP$_6$ w/o S-9	235
TA98/NR/1,8DNP$_6$ w/o S-9	603

ND = Not Done

TABLE 16

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Raw Exhaust at Full Load, 1600 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
500	147 85 159	130	100 ± 40	62 63 44 sl.tox.	56	36 ± 11
400	152 139 127	139	109 ± 13	59 52 54	55	35 ± 4
300	139 117 137	131	101 ± 12	63 58 79	67	47 ± 11
250	134 134 133	134	104 ± 0	69 84 58	70	50 ± 13
200	148 163 137	149	119 ± 13	57 69 83	70	50 ± 13
150	123 142 122	129	99 ± 11	64 57 62	61	41 ± 4
100	115 137 116	122	92 ± 12	52 44 70	55	35 ± 13
Controls: Negative Positive	 23 37 33 33 23 584 487 677	 30 583		 21 16 23 17 25 88 95 88	 20 90	
Specific Activity	0.27			0.15		

TABLE 16 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Raw Exhaust at Full Load, 1600 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98/1,8DNP$_6$ w/o S-9			TA98/NR/1,8DNP$_6$ w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
500	56 50	53	30 ± 4	22 -	22	7 ± 0
400	49 36	43	20 ± 9	34 30	32	17 ± 3
300	76 45	61	38 ± 22	38 42	40	25 ± 3
200	63 43	53	30 ± 14	26 32	29	14 ± 4
100	43 52	48	25 ± 6	18 20	19	4 ± 1
Controls:						
Negative	15 21 25 38 17	23		14 14 17 16 13	15	
Positive	100 101 118	106		78 54 48	60	
Specific Activity	0.07			0.18		

EVALUATION OF RAW DATA FROM TABLE 17A

Deutz 912 W Engine IncoCycle, Vent Fan Low

Soluble Organic Fraction	21.4 mg
Sampling Time	
Volume	14.9m^3
Dilution Ratio	33:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	47.4

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.41
TA98 w/ S-9	ND
TA98NR w/o S-9	Negative
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	19,432
TA98 w/ S-9	ND
TA98NR w/o S-9	Negative Mutagenic Response
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

8% Instantaneous CO$_2$

ND = Not Done

ORI

TABLE 17

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz FL912 W Engine, Inco Cycle, Vent Fan Low

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
800	175 147 169 Sl.Tox.	164	135 ± 15	Insufficient Sample	ND	-
600	171 138 122 Sl.Tox.	144	115 ± 25	37 62	50	34 ± 18
500	119 149 171	146	117 ± 26	Tox. 44 52	-	32 ± 7
400	148 175 162	162	133 ± 14	29 37 40	35	19 ± 7
350	128 112 124	121	92 ± 8	29 42 38	36	20 ± 7
300	170 121 151	147	118 ± 25	51 12 Tox. Tox.	Tox.	-
250	125 121 126	124	95 ± 3	13 Sl.Tox. 29 44	29	13 ± 16
200	116 112 119	116	87 ± 4	46 39 48	44	28 ± 5
150	100 105 122	109	80 ± 12	57 52 42	50	34 ± 8
100	91 86 83	87	58 ± 4	44 43 56	48	32 ± 7
80	61 48 50	53	24 ± 7	26 41 32	33	17 ± 8
60	41 34 45	40	11 ± 6	22 37 27	29	13 ± 8
40	35 42 36	38	9 ± 4	30 25 37	31	15 ± 6
20	33 41 56	43	14 ± 12	41 25 42	36	20 ± 10
Controls:						
Negative	33 24 35 28 26	29		11 14 11 28 15	16	
Positive	368 501 644	504		81 72 86	80	
Specific Activity	0.41			Negative		

EVALUATION OF RAW DATA FROM TABLE 18A

Deutz F6L 912 W Engine Inco Cycle, Vent Fan High

Soluble Organic Fraction	22.8 mg
Sampling Time	
Volume	$45.3 m^3$
Dilution Ratio	70:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	35.2

Specific Activity	(Revertants/μg)
TA98 w/o S-9	0.36
TA98 w/ S-9	ND
TA98NR w/o S-9	Negative
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	12683
TA98 w/ S-9	ND
TA98NR w/o S-9	Negative Mutagenic Response
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 18

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz FL912 W Engine, Inco Cycle, Vent Fan High

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
800	90 92 107	96	53 ± 9	Insufficient Sample	ND	
600	76 90 110	92	49 ± 17	25 50 39	38	12 ± 13
500	111 74 123	103	60 ± 26	23 28 16	22	0 ± 6
400	110 96 122	109	66 ± 13	21 25 31	26	0 ± 5
350	67 84 80	77	34 ± 9	6 10 12	9	0 ± 3
300	99 112 101	104	61 ± 7	Tox. 28 29	Tox.	-
250	70 91 95	85	42 ± 13	Tox. Tox. 22	Tox.	-
200	112 119 105	112	69 ± 7	Tox. Tox. 19	Tox.	-
150	87 129 115	110	67 ± 21	20 25 40	28	2 ± 10
100	100 103 105	103	60 ± 3	44 30 44	39	13 ± 8
80	45 36 55	45	2 ± 10	11 6 7	8	0 ± 3
60	51 60 43	51	8 ± 9	24 25 20	23	0 ± 3
40	57 41 53	50	7 ± 8	16 28 19	21	0 ± 6
20	47 54 48	50	7 ± 4	26 16 20	21	0 ± 5
Controls:						
Negative	49 38 48 35 47	43		27 29 28 19 26	26	
Positive	306 278 385	323		100 109 88	99	
Specific Activity	0.36			Negative		

EVALUATION OF RAW DATA FROM TABLE 19A

Deutz F8L 714 Engine Tested by Laurentian University Underground
(Mine Not in Production)

Soluble Organic Fraction	47.4 mg
Sampling Time	70 minutes
Volume	121.8m^3
Dilution Ratio	54.7:1
Collection Temperature	23.6^{o}C
Milligrams per cubic metre (mg/m3)	21.3

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.29
TA98 w/ S-9	ND
TA98NR w/o S-9	0.09
TA98/1,8DNP$_6$ w/o S-9	0.08
TA98/NR/1,8DNP$_6$ w/o S-9	Negative

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	6173
TA98 w/ S-9	ND
TA98NR w/o S-9	1917
TA98/1,8DNP$_6$ w/o S-9	1704
TA98/NR/1,8DNP$_6$ w/o S-9	Negative Mutagenicity

Instantaneous % CO_2	0.14
NO_x ppm	4
NO_2 ppm	0.1
CO ppm	3
SO_2 ppm	None Detected
CO right exhaust ppm	53 (raw exhaust)
CO left exhaust ppm	50 (raw exhaust)

ND = Not Done

TABLE 19

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F8L 714 Engine Tested by Laurentian University Underground (Mine Not in Production)

Concentration Filter Extracts µg/plate	Salmonella Tester Strain							
	TA98 w/o S-9				TA98NR w/o S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1000	264	287	275	246 ± 16	112	107	110	75 ± 4
800	237	299	268	239 ± 44	92	89	91	56 ± 2
600	212	250	231	202 ± 17	83	105	94	59 ± 16
500	198	222	210	181 ± 17	87	84	86	51 ± 2
400	197	173	185	156 ± 17	95	84	90	55 ± 8
300	172	153	163	134 ± 13	66	88	77	42 ± 16
200	123	131	127	98 ± 6	66	63	65	30 ± 2
100	93	92	93	64 ± 1	48	58	53	18 ± 7
50	69	76	73	44 ± 5	58	34	46	11 ± 16
Controls:								
Negative	29 31 31 24 30		29		34 30 44 39 29		35	
Positive	433 476 565		491		115 98 96		103	
Specific Activity	0.29				0.09			

TABLE 19 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F8L 714 Engine Tested by Laurentian University Underground (Mine Not in Production)

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	61 64	63	49 ± 2	12 15	14	3 ± 2
800	62 41	52	38 ± 15	15 21	18	7 ± 5
600	47 55	51	37 ± 6	13 26	20	9 ± 9
500	49 60	55	41 ± 8	18 13	16	5 ± 4
400	52 53	53	39 ± 1	4 13	9	0 ± 1
300	28 35	32	18 ± 5	19 14	17	6 ± 2
200	34 31	33	19 ± 2	21 9	15	4 ± 8
100	27 21	24	10 ± 5	16 16	16	5 ± 0
50	16 26	21	7 ± 7	9 9	9	0 ± 0
Controls:						
Negative	13 24 13 10 12	14		9 12 13 8 13	11	
Positive	63 88 88	80		43 62 45	50	
Specific Activity	0.08			Negative		

EVALUATION OF RAW DATA FROM TABLE 20A

Deutz F8L 714 Engine Tested by Laurentian University Underground
(Mine Not in Production)

Soluble Organic Fraction	37.3 mg
Sampling Time	68 minutes
Volume	$120.9 m^3$
Dilution Ratio	97.2:1
Collection Temperature	23.3°C
Milligrams per cubic metre (mg/m3)	29.98

Specific Activity	(Revertants/μg)
TA98 w/o S-9	0.19
TA98 w/ S-9	ND
TA98NR w/o S-9	0.10
TA98/1,8DNP$_6$ w/o S-9	Negative
TA98/NR/1,8DNP$_6$ w/o S-9	Negative

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	5698
TA98 w/ S-9	ND
TA98NR w/o S-9	2998
TA98/1,8DNP$_6$ w/o S-9	Negative Mutagenicity
TA98/NR/1,8DNP$_6$ w/o S-9	Negative Mutagenicity

Instantaneous % CO_2	0.09%
NO_x ppm	6
NO_2 ppm	0.11
CO ppm	4
SO_2 ppm	None Detected
CO right exhaust ppm	52 (raw exhaust)
CO left exhaust ppm	55 (raw exhaust)

ND = Not Done

TABLE 20

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F8L 714 Engine Tested by Laurentian University Underground (Mine Not In Production)

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	179 180	180	151 ± 1	73 54	64	29 ± 13
800	181 160	170	141 ± 15	69 50	60	25 ± 13
600	164 147	155	126 ± 12	64 63	64	29 ± 1
500	142 154	148	119 ± 9	78 96	87	52 ± 13
400	119 122	121	92 ± 2	50 64	57	22 ± 10
300	94 122	108	79 ± 20	59 60	60	25 ± 1
200	89 99	94	65 ± 7	46 56	51	16 ± 7
100	74 74	74	45 ± 0	43 40	42	7 ± 2
50	35 52	44	15 ± 12	31 35	33	0 ± 3
Controls:						
Negative	29 31 31 24 30	29		34 30 44 39 29	35	
Positive	433 476 565	491		115 98 96	103	
Specific Activity	0.19			0.10		

TABLE 20(Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F8L 714 Engine Tested by Laurentian University Underground (Mine Not In Production)

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	15 7	11	0 ± 7	11 10	11	0 ± 1
800	1 4 Tox.	Tox.	0 ± 3	14 22	18	7 ± 6
600	5 14	10	0 ± 8	14 12	13	1 ± 1
500	6 15	11	0 ± 7	10 7	9	0 ± 3
400	8 15	12	0 ± 6	10 15	13	2 ± 3
300	2 1	2	0 ± 1	13 15	14	3 ± 1
200	2 3	3	0 ± 1	7 11	9	0 ± 3
100	4 6	5	0 ± 1	8 11	10	0 ± 3
50	2 2	2	0 ± 0	11 13	2	1 ± 1
Controls:						
Negative	13 24 23 10 12	14		9 12 13 8 13	11	
Positive	63 88 88	80		43 62 45	50	
Specific Activity	Negative			Negative		

EVALUATION OF RAW DATA FROM TABLE 21

Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load and 2200 rpm

Soluble Organic Fraction	145.9 mg
Sampling Time	150 minutes
Volume	85m^3
Dilution Ratio	16:1
Collection Temperature	62°C
Milligrams per cubic metre (mg/m3)	27.5

Specific Activity	(Revertants/μg)
TA98 w/o S-9	4.01
TA98 w/ S-9	1.7
TA98NR w/o S-9	1.77
TA98/1,8DNP$_6$ w/o S-9	0.128
TA98/NR/1,8DNP$_6$ w/o S-9	0.073

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	110,131
TA98 w/ S-9	46,689
TA98NR w/o S-9	48,611
TA98/1,8DNP$_6$ w/o S-9	3,515
TA98/NR/1,8DNP$_6$ w/o S-9	2,005

ND = Not Done

TABLE 21

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and PTX Catalyst 7/8 Load and 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain							
	TA98 w/o S-9				TA98 w/ S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1500	3780	3337	3559	3525 ± 313	2117	2182	2150	2103 ± 46
750	3121	2981	3051	3017 ± 99	1480	1069	1275	1228 ± 291
300	1490	1253	1372	1338 ± 168	448	460	454	407 ± 9
150	901	784	843	809 ± 82	270	260	265	218 ± 7
120	407	443	425	391 ± 26	154	143	149	102 ± 8
60	268	316	292	258 ± 34	104	90	97	50 ± 10
30	164	-	164	130	75	68	72	25 ± 5
Controls:								
Negative	43 30 34 25 39		34		40 53 49 56 39		47	
Positive	548 498 592		546		1469 1836 1253		1519	
Specific Activity	4.01				1.7			

TABLE 21 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and PTX Catalyst 7/8 Load and 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain								
	TA98NR w/o S-9			TA98/1,8DNP$_6$ w/o S-9			TA98/NR/1,8DNP$_6$ w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1500	1447 1480	1464	1449 ± 23	210 202	206	189 ± 6	86 96	91	76 ± 6
750	1328 1253	1291	1276 ± 53	186 174	180	163 ± 9	71 76	74	59 ± 4
300	442 445	444	429 ± 2	93 115	104	87 ± 16	34 34	34	19 ± 0
150	262 192	227	212 ± 50	38 65	52	35 ± 9	27 35	31	16 ± 6
120	124 142	133	118 ± 13	42 34	38	21 ± 6	32 22	27	12 ± 7
60	66 61	64	49 ± 4	30 32	31	14 ± 1	18 25	22	7 ± 5
30	27 31	29	14 ± 3	30 36	33	16 ± 4	19 21	20	5 ± 1
Controls: Negative	19 11 10 14 19	15		16 13 29 18 10	17		10 11 24 15 15	15	
Positive	86 63 102	84		89 51 61	67		55 66 64	63	
Specific Activity	1.77			0.128			0.073		

EVALUATION OF RAW DATA FROM TABLE 22A

Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load, 2200 rpm

Soluble Organic Fraction	26.4 mg
Sampling Time	80 minutes
Volume	$44 m^3$
Dilution Ratio	
Collection Temperature	
Milligrams per cubic metre (mg/m3)	9.6

Specific Activity	(Revertants/μg)
TA98 w/o S-9	7.81
TA98 w/ S-9	ND
TA98NR w/o S-9	2.64
TA98/1,8DNP$_6$ w/o S-9	0.328
TA98/NR/1,8DNP$_6$ w/o S-9	0.18

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	74,976
TA98 w/ S-9	ND
TA98NR w/o S-9	25,344
TA98/1,8DNP$_6$ w/o S-9	3,149
TA98/NR/1,8DNP$_6$ w/o S-9	1,728

ND = Not Done

TABLE 22

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	3424	3424	3376	929	929	899
900	3078	3078	3030	1145	1145	1115
800	3013	3013	2965	1264	1264	1234
700	3240	3240	3192	1177	1177	1147
600	3240	3240	3192	972	972	942
500	2700	2700	2652	1112	1112	1082
400	3013	3013	2965	1004	1004	974
300	2236	2236	2188	725	725	695
200	1663	1663	1615	500	500	470
100	1208	1208	1160	281	281	251
90	378 414	396	348 ± 26	106 101	104	74 ± 4
80	352 403	378	330 ± 36	104 110	107	77 ± 4
70	339 367	353	305 ± 20	100 117	109	79 ± 12
60	378 394	386	338 ± 11	130 114	122	92 ± 11
50	375 371	373	325 ± 3	122 119	121	91 ± 2
Controls:						
Negative	42 48 56 59 36	48		35 28 29 36 24	30	
Positive	309 533 332	391		100 86 126	104	
Specific Activity	7.81			2.64		

TABLE 22 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98/1,8 DNP$_6$ w/o S-9			TA98/NR/1,8 DNP$_6$ w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	172	172	154	135	135	91
900	171	171	153	156	156	112
800	151	151	133	135	135	91
700	185	185	167	118	118	74
600	165	165	147	141	141	97
500	156	156	138	147	147	103
400	123	123	105	115	115	71
300	106	106	88	88	88	44
200	88	88	70	77	77	33
100	64	64	46	57	57	13
90	23	23	5	49	49	5
80	16	16	0	40	40	0
70	16	16	0	47	47	3
60	11	11	0	38	38	0
50	17	17	0	69	69	25
Controls:						
Negative	14 14 33 13 17	18		50 32 49 36 52	44	
Positive	67 62 60	64		154 192 134	160	
Specific Activity	0.328			0.18		

EVALUATION OF RAW DATA FROM TABLE 23A

Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load, 2200 rpm

Soluble Organic Fraction	22.6 mg
Sampling Time	20 minutes
Volume	$11m^3$
Dilution Ratio	16:1
Collection Temperature	50^oC
Milligrams per cubic metre (mg/m3)	32.8

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.935
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	44,608
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 23

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load and 2200 rpm

Concentration Filter Extracts μg/plate	Salmonella Tester Strain				
	TA98 w/o S-9				
	Histidine Revertants			Average	Net Revertants ± Standard Deviation
1000	425	411	531	456	428 ± 66
900	412	379	515	435	407 ± 71
800	513	440	538	497	469 ± 51
700	453	505	435	464	436 ± 35
600	487	428	404	440	412 ± 43
500	376	408	369	384	356 ± 21
400	530	436	522	496	468 ± 52
300	325	373	400	366	338 ± 38
200	311	327	327	322	294 ± 9
100	213	195	199	202	174 ± 10
90	93	93	72	86	58 ± 12
80	63	68	60	64	36 ± 4
70	61	75	74	70	42 ± 8
60	78	65	59	67	39 ± 10
50	53	61	64	59	31 ± 6
Controls:					
Negative	20 27	27 26	41	28	
Positive	516	513	382	470	
Specific Activity		0.935			

EVALUATION OF RAW DATA FROM TABLE 24A

Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load and 2200 rpm
(1/5th Sampling Time per Filter)

Soluble Organic Fraction	201.8 mg
Sampling Time	204 minutes
Volume	119m^3
Dilution Ratio	16:1
Collection Temperature	62^{0}C
Milligrams per cubic metre (mg/m3)	27.1

Specific Activity	(Revertants/μg)
TA98 w/o S-9	2.28
TA98 w/ S-9	1.24
TA98NR w/o S-9	0.696
TA98/1,8DNP$_6$ w/o S-9	0.098
TA98/NR/1,8DNP$_6$ w/o S-9	0.030

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	61,863
TA98 w/ S-9	33,645
TA98NR w/o S-9	18,884
TA98/1,8DNP$_6$ w/o S-9	2,659
TA98/NR/1,8DNP$_6$ w/o S-9	814

ND = Not Done

TABLE 24

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load and 2200 rpm (1/5th Sampling Time per Filter)

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98 w/ S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1500	2020 2473	2247	2213 ± 320	1404 1264	1334	1294 ± 99
750	1631 1771	1701	1667 ± 99	1069 821	945	905 ± 175
300	788 821	805	771 ± 23	297 312	305	265 ± 11
150	348 325	337	303 ± 16	142 216	179	139 ± 52
120	236 187	212	178 ± 35	98 106	102	62 ± 6
60	149 166	158	124 ± 12	94 102	98	58 ± 6
30	108 87	98	64 ± 15	54 68	61	21 ± 10
Controls:						
Negative	29 36 34 32 39	34		48 34 46 32 39	40	
Positive	592 1069 670	777		2063 1598 1836	1832	
Specific Activity	2.28			1.24		

TABLE 24 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and PTX Catalyst at 7/8 Load and 2200 rpm (1/5th Sampling Time per Filter)

Concentration Filter Extracts µg/plate	Salmonella Tester Strain								
	TA98NR w/o S-9			TA98/1,8DNP$_6$ w/o S-9			TA98/NR/1,8DNP$_6$ w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1500	580 648	614	606 ± 48	183 149	166	135 ± 24	59 65	62	44 ± 4
750	520 516	518	510 ± 3	115 140	128	97 ± 18	50 45	48	30 ± 4
300	242 232	237	229 ± 7	69 64	67	36 ± 4	27 28	28	10 ± 1
150	102 119	111	103 ± 12	36 44	40	9 ± 6	25 20	23	5 ± 3
120	59 63	61	53 ± 3	20 25	23	0 ± 4	25 21	23	5 ± 4
60	38 42	40	32 ± 3	27 20	24	0 ± 5	24 14	19	1 ± 7
30	29 35	32	24 ± 4	35 41	38	7 ± 4	20 14	17	0 ± 4
Controls: Negative	7 8 7 5 13	8		21 34 34 37 27	31		15 23 13 23 17	18	
Positive	68 98 67	78		93 106 122	107		68 74 71	71	
Specific Activity	0.696			0.098			0.030		

EVALUATION OF RAW DATA FROM TABLE 25A

Deutz F6L 714 Engine and Dieseler III Catalyst
at 7/8 Load, 2200 rpm, Probe Heated

Soluble Organic Fraction	172.2 mg
Sampling Time	120 minutes
Volume	68m^3
Dilution Ratio	16:1
Collection Temperature	50°C
Milligrams per cubic metre (mg/m3)	40.5

Specific Activity	(Revertants/μg)
TA98 w/o S-9	0.75
TA98 w/ S-9	ND
TA98NR w/o S-9	0.175
TA98/1,8DNP$_6$ w/o S-9	0.078
TA98/NR/1,8DNP$_6$ w/o S-9	0.014

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	30,388
TA98 w/ S-9	ND
TA98NR w/o S-9	7,091
TA98/1,8DNP$_6$ w/o S-9	3,160
TA98/NR/1,8DNP$_6$ w/o S-9	567

ND = Not Done

ORI

TABLE 25

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	354 374	364	314 ± 14	170 146	158	133 ± 17
900	388 384	386	336 ± 3	159 177	168	143 ± 13
800	454 360	407	357 ± 66	155 141	148	123 ± 10
700	349 383	366	316 ± 24	157 148	153	128 ± 6
600	378 437	408	358 ± 42	133 143	138	113 ± 7
500	357 381	369	319 ± 17	117 112	115	90 ± 4
400	348 323	336	286 ± 18	110 93	102	77 ± 12
300	283 248	266	216 ± 25	105 88	97	72 ± 12
200	227 220	224	174 ± 5	64 78	71	46 ± 10
100	152 177	165	115 ± 18	57 51	54	29 ± 4
80	108 56	82	32 ± 37	36 25	31	6 ± 8
60	38 24	31	0 ± 10	84 71	78	53 ± 9
40	76 71	74	24 ± 4	32 34	33	8 ± 1
20	64 59	62	12 ± 4	20 27	24	0 ± 5
10	62 61	62	12 ± 1	27 32	30	5 ± 4
Controls:						
Negative	50 41 42 47 68	50		26 32 20 18 31	25	
Positive	463 602 324	463		93 92 123	103	
Specific Activity	0.75			(0.175)		

TABLE 25 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants + Standard Deviation
1000	57	57	38	50	50	24
900	61	61	42	42	42	16
800	63	63	44	50	50	24
700	69	69	50	40	40	14
600	63	63	44	21	21	0
500	57	57	38	32	32	6
400	53	53	34	38	38	12
300	45	45	26	29	29	3
200	37	37	18	23	23	0
100	21	21	2	24	24	0
80	13	13	0	18	18	0
60	16	16	0	30	30	4
40	22	22	3	14	14	0
20	16	16	0	20	20	0
10	21	21	2	19	19	0
Controls:						
Negative	21 21 19 14 18	19		25 26 25 26 27	26	
Positive	82 72 55	70		102 99 93	98	
Specific Activity	0.078			0.014		

EVALUATION OF RAW DATA FROM TABLE 26A

Deutz F6L 714 Engine and Dieseler III Catalyst
at 7/8 Load, 2200 rpm, Probe Heated

Soluble Organic Fraction	30.9 mg
Sampling Time	30 minutes
Volume	17m^3
Dilution Ratio	16:1
Collection Temperature	50°C
Milligrams per cubic metre (mg/m3)	29.0

Specific Activity	(Revertants/μg)
TA98 w/o S-9	0.41
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m3 Undiluted Exhaust)
TA98 w/o S-9	11,924
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 26

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain			
	TA98 w/o S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1000	292	305	299	249 ± 9
900	275	292	284	234 ± 12
800	289	279	284	234 ± 7
700	301	311	306	256 ± 7
600	293	276	285	235 ± 12
500	269	247	258	208 ± 16
400	193	230	212	162 ± 26
300	194	203	199	149 ± 6
200	171	149	160	110 ± 16
100	125	133	129	79 ± 6
80	61	51	56	6 ± 7
60	60	71	66	16 ± 8
40	55	59	57	7 ± 3
20	51	49	50	0 ± 1
10	51	71	61	11 ± 14
Controls:				
Negative	50 41 42 47 68		50	
Positive	463 602 324		463	
Specific Activity	0.41			

EVALUATION OF RAW DATA FROM TABLE 29A

Deutz F6L 714 Engine and Dieseler III Catalyst
at 7/8 Load, 2200 rpm, Probe Not Heated

Soluble Organic Fraction	26.6 mg
Sampling Time	90 minutes
Volume	51m^3
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	8.3

Specific Activity	(Revertants/μg)
TA98 w/o S-9	50.79
TA98 w/ S-9	ND
TA98NR w/o S-9	39.12
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	423,873
TA98 w/ S-9	ND
TA98NR w/o S-9	326,480
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 29

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Not Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	25,000 14,700 15,100	18,300	18,261 ± 5835	9400 10,400 11,500	10,400	10,366 ± 1050
800	10,000 10,900 12,600	11,200	11,161 ± 1320	12,800 11,900 12,600	12,400	12,366 ± 473
600	12,700 16,500 8900	12,700	12,661 ± 3800	16,500 14,300 12,700	14,500	14,466 ± 1908
400	11,100 13,000 12,600	12,200	12,161 ± 1002	14,000 15,700 13,500	14,400	14,366 ± 1153
200	7300 9500 12,900	9900	9861 ± 2021	8316 12,300 11,400	10,700	10,666 ± 2089
100	6600 5200 7100	6300	6261 ± 985	8766 4536 6426	6600	6566 ± 2119
80	3089 2992 2387	2823	2784 ± 380	1064 1609 1382	1352	1318 ± 274
60	2214 2992 2300	2502	2463 ± 427	1044 1307 1640	1330	1296 ± 299
40	2074 1993 1490	1832	1793 ± 305	862 820 867	850	816 ± 26
20	846 1436 1069	1117	1078 ± 298	418 469 403	430	396 ± 35
10	532 446 533	504	465 ± 50	216 222 240	226	192 ± 13
Controls:						
Negative	31 47 38 32 46	39		35 24 31 43 35	34	
Positive	424 554 406	416		155 93 115	121	
Specific Activity	50.79			39.12		

ORI

EVALUATION OF RAW DATA FROM TABLE 30A

Deutz F6L 714 Engine and Dieseler III Catalyst
at 7/8 Load, 2200 rpm, Probe Not Heated

Soluble Organic Fraction	18 mg
Sampling Time	60 minutes
Volume	$34m^3$
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	8.5

Specific Activity	(Revertants/ug)
TA98 w/o S-9	13.47
TA98 w/ S-9	ND
TA98NR w/o S-9	9.22
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	114,096
TA98 w/ S-9	ND
TA98NR w/o S-9	78,097
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 30

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Diesler III Catalyst at 7/8 Load, 2200 rpm, Probe Not Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain							
	TA98 w/o S-9				TA98NR w/o S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1000	4860	4277	4569	4540 ± 412	6016	4957	5487	5459 ± 749
800	11,232	9644	10,440	10,411 ± 1123	7560	6534	7047	7019 ± 725
600	9612	7792	8703	8674 ± 1286	5206	5400	5303	5275 ± 137
400	6804	6188	6496	6467 ± 436	4018	4363	4192	4164 ± 244
200	3791	3024	3408	3379 ± 542	1901	1696	1799	1771 ± 145
100	2376	2398	2387	2358 ± 16	780	732	756	728 ± 34
80	1253	1069	1162	1133 ± 130	312	307	310	282 ± 4
60	1037	950	994	965 ± 62	290	291	291	263 ± 1
40	602	597	600	571 ± 4	199	208	204	176 ± 6
20	245	301	273	244 ± 40	109	118	114	86 ± 6
10	178	168	173	144 ± 7	63	59	61	33 ± 3
Controls:								
Negative	36 30 28	28 21	29		34 25 22	27 31	28	
Positive	607 459	581	545		113 107	98	106	
Specific Activity	13.47				9.22			

EVALUATION OF RAW DATA FROM TABLE 27A

Deutz F6L 714 Engine and Dieseler III Catalyst
at 7/8 Load, 2200 rpm, Probe Heated

Soluble Organic Fraction	28 mg
Sampling Time	30 minutes
Volume	$17m^3$
Dilution Ratio	16:1
Collection Temperature	50^oC
Milligrams per cubic metre (mg/m3)	26.3

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.54
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	14,231
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 27

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain			
	TA98 w/o S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1000	332	305	319	269 ± 19
900	299	277	288	238 ± 16
800	327	337	282	232 ± 7
700	301	292	297	247 ± 6
600	320	351	336	286 ± 22
500	276	327	302	252 + 36
400	257	319	288	238 ± 44
300	229	244	237	187 ± 11
200	204	209	207	157 ± 4
100	126	151	139	89 ± 18
80	69	95	82	32 ± 18
60	60	87	74	24 ± 19
40	82	66	74	24 ± 11
20	60	61	61	11 ± 1
10	71	65	68	18 ± 4
Controls:				
Negative	50 41 42 47 68		50	
Positive	463 602 324		463	
Specific Activity	0.54			

EVALUATION OF RAW DATA FROM TABLE 28A

Deutz F6L 714 Engine and Dieseler III Catalyst
at 7/8 Load, 2200 rpm, Probe Heated

Soluble Organic Fraction	25.8 mg
Sampling Time	120 minutes
Volume	$68m^3$
Dilution Ratio	16:1
Collection Temperature	50^oC
Milligrams per cubic metre (mg/m3)	6.1

Specific Activity	(Revertants/μg)
TA98 w/o S-9	3.19
TA98 w/ S-9	ND
TA98NR w/o S-9	1.17
TA98/1,8DNP$_6$ w/o S-9	0.12
TA98/NR/1,8DNP$_6$ w/o S-9	0.10

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	19,365
TA98 w/ S-9	ND
TA98NR w/o S-9	7103
TA98/1,8DNP$_6$ w/o S-9	729
TA98/NR/1,8DNP$_6$ w/o S-9	607

ND = Not Done

TABLE 28

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	2030	2030	1980	481	481	456
800	2182	2182	2132	658	658	633
600	1922	1922	1872	689	689	664
400	1437	1437	1387	576	576	551
200	925	925	875	240	240	215
100	546	546	496	176	176	151
80	238	238	188	113	113	88
60	242	242	192	105	105	80
40	216	216	166	72	72	47
20	126	126	76	50	50	25
10	98	98	48	39	39	14
Controls:						
Negative	50 41 42 47 68	50		26 32 20 18 31	25	
Positive	463 602 324	463		93 92 123	103	
Specific Activity	3.19			1.17		

TABLE 28 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	128	128	109	120	120	94
800	118	118	99	110	110	84
600	110	110	91	107	107	81
400	94	94	75	80	80	54
200	43	43	28	47	47	21
100	31	31	12	48	48	22
80	33	33	14	32	32	6
60	34	34	15	44	44	18
40	29	29	10	22	22	0
20	22	22	3	20	20	0
10	21	21	2	17	17	0
Controls:						
Negative	21 21 19 14 18	19		25 26 25 26 27	26	
Positive	72 82 55	70		102 99 93	98	
Specific Activity	0.12			0.10		

EVALUATION OF RAW DATA FROM TABLE 31A

Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Soluble Organic Fraction	28 mg
Sampling Time	120 minutes
Volume	$68 m^3$
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	6.6

Specific Activity	(Revertants/μg)
TA98 w/o S-9	11.14
TA98 w/ S-9	ND
TA98NR w/o S-9	5.63
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	73,399
TA98 w/ S-9	ND
TA98NR w/o S-9	37,095
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 31

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain							
	TA98 w/o S-9				TA98NR w/o S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1000	3542	4644	4093	4064 ± 779	1987	1955	1974	1943 ± 23
800	5087	5897	5492	5463 ± 573	2279	1825	2052	2024 ± 321
600	4363	4838	4601	4572 ± 336	2797	2138	2468	2440 ± 466
400	3834	4547	4191	4162 ± 504	2354	1922	2138	2110 ± 305
200	2916	2365	2641	2612 ± 390	1172	1361	1267	1239 ± 134
100	1555	1102	1329	1300 ± 320	466	918	692	664 ± 320
80	467	431	449	420 ± 26	267	203	235	207 ± 45
60	368	410	389	360 ± 30	189	189	189	161 ± 0
40	326	261	294	265 ± 46	131	169	150	122 ± 27
20	199	206	203	174 ± 5	77	78	78	50 ± 1
10	104	119	112	83 ± 11	65	73	69	41 ± 7
Controls:								
Negative	36 30 28	28 21	29		34 25 22	27 31	28	
Positive	607 459	581	545		113 107	98	106	
Specific Activity	11.14				5.63			

EVALUATION OF RAW DATA FROM TABLE 32A

Deutz F6L 714 Engine and Dieseler III Catalyst
at 7/8 Load, 2200 rpm, Probe Heated

Soluble Organic Fraction	13.2 mg
Sampling Time	30 minutes
Volume	17m^3
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	12.4

Specific Activity	(Revertants/μg)
TA98 w/o S-9	1.85
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	22,984
TA98 w/ S-9	ND
TA98NR w/o S-9	ND
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 32

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain		
	TA98 w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	918 1274 1004	1065	1026 ± 186
800	1102 1091 1382	1192	1153 ± 165
600	1123 1004 1004	1044	1005 ± 69
400	983 961 685	876	837 ± 166
200	356 433 435	408	369 ± 45
100	257 238 279	258	219 ± 21
80	79 65 77	74	35 ± 8
60	76 66 79	74	35 ± 7
40	67 63 66	65	26 ± 2
20	61 61 62	61	22 ± 1
10	65 61 62	63	24 ± 2
Controls:			
Negative	31 47 38 32 46	39	
Positive	424 554 406	416	
Specific Activity	1.85		

EVALUATION OF RAW DATA FROM TABLE 33A

Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Soluble Organic Fraction	18.5 mg
Sampling Time	60 minutes
Volume	$34 m^3$
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	8.7

Specific Activity	(Revertants/μg)
TA98 w/o S-9	1.14
TA98 w/ S-9	ND
TA98NR w/o S-9	0.49
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	9925
TA98 w/ S-9	ND
TA98NR w/o S-9	4266
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

ORF

TABLE 33

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Heated

Concentration Filter Extracts µg/plate	Salmonella Tester Strain							
	TA98 w/o S-9				TA98NR w/o S-9			
	Histidine Revertants		Average	Net Revertants ± Standard Deviation	Histidine Revertants		Average	Net Revertants ± Standard Deviation
1000	654	639	647	618 ± 11	328	305	317	289 ± 16
800	655	749	702	673 ± 66	299	251	275	247 ± 34
600	663	738	701	672 ± 53	289	345	317	289 ± 40
400	584	479	532	503 ± 74	213	220	217	189 ± 5
200	264	359	312	283 ± 67	122	143	133	105 ± 15
100	205	248	227	198 ± 30	85	74	80	52 ± 8
80	103	116	110	81 ± 9	53	57	55	27 ± 3
60	95	100	98	69 ± 4	45	52	49	21 ± 5
40	87	70	79	50 ± 12	32	48	40	12 ± 11
20	71	49	60	31 ± 16	45	32	39	11 ± 9
10	49	60	55	26 ± 8	16	10	13	0 ± 4
Controls:								
Negative	36 30 28 28 21		29		34 25 22 27 31		28	
Positive	607 459 581		545		113 107 98		106	
Specific Activity	1.14				0.49			

EVALUATION OF RAW DATA FROM TABLE 34A

Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load,
2200 rpm, Probe Not Heated. Storage Effect Examined

Soluble Organic Fraction	23.8 mg
Sampling Time	½ hr. sample, ½ hr. at ½ load no sample
Volume	$51 m^3$
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	7.5

Specific Activity	(Revertants/µg)
TA98 w/o S-9	8.75
TA98 w/ S-9	ND
TA98NR w/o S-9	4.84
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	65,338
TA98 w/ S-9	ND
TA98NR w/o S-9	36,117
TA98/1,8DNP$_6$ w/o S-9	ND
TA98/NR/1,8DNP$_6$ w/o S-9	ND

ND = Not Done

TABLE 34A

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Dieseler III Catalyst at 7/8 Load, 2200 rpm, Probe Not Heated. Storage Effect Examined

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98NR w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	2344 2549 2927 Sl.Tox.	2607	2568 ± 296	1663 1739	1701	1667 ± 54
800	2592	2592	2553	1912 2030 1760	1901	1867 ± 135
600	3390 2030 2624	2675	2636 ± 558	1847 1458 1944	1750	1910 ± 257
400	2516 2905 2452	2624	2585 ± 245	1588 2171 1847	1869	1813 ± 292
200	1663 1512 1674	1616	1577 ± 91	852 799 1102	918	884 ± 161
100	1480 1123 1231	1278	1239 ± 183	395 479 574	483	449 ± 90
80	258 176 289	241	202 ± 58	123 110 130	121	87 ± 10
60	250 286 240	259	220 ± 24	129 111 128	123	89 ± 10
40	179 196 196	190	151 ± 10	108 96 86	97	63 ± 11
20	114 133 193	147	108 ± 41	87 80 94	87	53 ± 7
10	99 107 97	101	62 ± 5	79 72 69	73	39 ± 5
Controls:						
Negative	31 47 38 32 46	39		35 24 31 43 35	34	
Positive	424 554 406	416		155 93 115	121	
Specific Activity	8.75			4.84		

TABLE 35

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Johnson Matthey Catalyst at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain					
	TA98 w/o S-9			TA98 w/S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	646 660 626	644	587 ± 17	848 1258 1598	1231	1173 ± 376
800	605 715 742	687	630 ± 73	1685 1498 1339	1507	1449 ± 173
600	620 758 604	661	604 ± 85	1404 1231 961	1199	1143 ± 223
500	580 659 516	585	528 ± 72	1045 1501 1609	1385	1327 ± 300
400	551 669 675	632	575 ± 70	964 1177 1285	1142	1084 ± 163
350	259 326 265	283	226 ± 37	468 573 563	535	477 ± 58
300	318 318 334	323	266 ± 9	602 596 542	580	522 ± 33
250	313 303 294	303	246 ± 10	548 445 603	532	474 ± 80
200	322 304 365	330	273 ± 31	385 395 387	389	331 ± 6
150	304 271 275	283	226 ± 18	565 430 498	498	440 ± 95
100	233 227 246	235	178 ± 10	289 253 355	299	239 ± 52
80	156 123 144	141	84 ± 17	180 235 194	203	145 ± 29
40	101 128 135	121	64 ± 18	124 127 107	119	61 + 11
20	103 125 77	102	45 ± 24	83 82 83	83	25 ± 1
Controls:						
Negative	55 62 46 62 62	57		53 53 70 62 54	58	
Positive	371 395 388	385		1426 1966 1706	1699	
Specific Activity	0.97			0.27		

EVALUATION OF RAW DATA FROM TABLE 35A

Deutz F6L 714 Engine and Johnson Matthey Catalyst at 7/8 Load, 2200 rpm

Soluble Organic Fraction	114.1 mg
Sampling Time	240 minutes
Volume	$136 m^3$
Dilution Ratio	16:1
Collection Temperature	
Milligrams per cubic metre (mg/m3)	13.4

Specific Activity	(Revertants/µg)
TA98 w/o S-9	0.97
TA98 w/ S-9	0.27
TA98NR w/o S-9	0.28
TA98/1,8DNP$_6$ w/o S-9	0.07
TA98/NR/1,8DNP$_6$ w/o S-9	Negative

Total Mutagenicity	(Revertants/m^3 Undiluted Exhaust)
TA98 w/o S-9	13,021
TA98 w/ S-9	3,625
TA98NR w/o S-9	3,759
TA98/1,8DNP$_6$ w/o S-9	940
TA98/NR/1,8DNP$_6$ w/o S-9	Negative Mutagenic Response

ND = Not Done

TABLE 35 (Contd.)

Ames Mutagenicity Plate Incorporation Assay Results for Dichloromethane Extractables from Hi Vol Filters of Deutz F6L 714 Engine and Johnson Matthey Catalyst at 7/8 Load, 2200 rpm

Concentration Filter Extracts µg/plate	Salmonella Tester Strain								
	TA98NR w/o S-9			TA98/1,8DNP$_6$ w/o S-9			TA98/NR/1,8DNP$_6$ w/o S-9		
	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation	Histidine Revertants	Average	Net Revertants ± Standard Deviation
1000	172 170 208	183	165 ± 21	139 105 135	126	120 ± 19	25 37 30	31	20 ± 6
800	171 191 183	182	164 ± 10	130 122 109	120	114 ± 11	19 29 30	26	15 ± 6
600	147 175 170	164	146 ± 15	36 35 59	43	37 ± 14	20 29 23	24	13 ± 5
500	162 145 152	153	135 ± 9	51 46 74	57	51 ± 15	27 21 24	24	13 ± 3
400	163 142 165	153	135 ± 11	18 52 38	36	30 ± 17	13 27 22	21	10 ± 7
350	120 114 95	110	92 ± 13	11 24 28	21	15 ± 9	18 21 13	17	6 ± 4
300	144 105 96	115	97 ± 26	23 23 37	28	22 ± 8	22 18 22	21	10 ± 2
250	84 105 92	94	76 ± 11	9 17 45	24	18 ± 19	19 26 18	21	10 ± 4
200	103 95 99	99	81 ± 4	9 14 27	17	11 ± 9	22 18 22	21	10 ± 1
150	97 79 75	84	66 ± 12	20 16 37	24	18 ± 11	16 14 13	14	3 ± 2
100	74 67 70	70	52 ± 4	1 1 3	2	0 ± 0	19 13 18	17	6 ± 3
80	51 49 39	46	28 ± 6	10 30 19	20	14 ± 10	14 7 8	10	0 ± 2
40	41 39 41	40	22 ± 3	8 11 16	12	6 ± 4	12 13 12	12	1 ± 1
20	30 22 29	27	9 ± 4	17 14 11	14	8 ± 3	7 15 11	11	0 ± 2
Controls: Negative	19 12 24 17 18	18		6 5 6 6 6	6		12 8 10 18 7	11	
Positive	89 75 73	79		48 49 50	49		48 30 48	42	
Specific Activity	0.28			0.07			Negative		

Table 36

Ames Diesel Particulate Data
Baseline

Deutz F6L 714

RPM/ °C	kW	Soluble				Insoluble				Total				% Soluble	% Insoluble
		mg/m^3	g/hr	g/kW. hr	g/kg (fuel)	mg/m^3	g/hr	g/kW. hr	g/kg (fuel)	mg/m^3	g/hr	g/kW. hr	g/kg (fuel)		
2200/ 441°C	78.4 78.4	51.21 44.91	25.224 21.979	0.322 0.28	1.226 1.075	52.39 46.36	25.803 22.688	0.329 0.289	1.254 1.109	103.6 91.26	51.027 44.668	0.651 0.57	2.479 2.184	49.4 49.2	50.6 50.8
2200/ 340°C	52.5 52.5	94.59 70.66	48.537 35.876	0.925 0.684	3.018 2.255	54.59 57.33	28.014 29.109	0.534 0,555	1.742 1.830	149.18 127.99	76.551 64.985	1.459 1.238	4.761 4.085	63.4 55.2	36.6 44.8
1900/ 402°C	71.8 71.8	32.45 39.22	13.507 16.459	0.188 0.229	0.782 0.945	59.2 58.54	24.642 24.562	0.343 0.342	1.427 1.411	91.65 97.76	38.149 41.021	0.532 0.572	2.209 2.356	35.4 40.1	64.6 59.9
1900/ 306°C	48.0 48.0	55.57 62.57	23.921 27.097	0.498 0.564	1.807 2.034	54.72 54.3	23.554 23.517	0.491 0.49	1.779 1.766	110.29 116.87	47.476 50.614	0.989 1.054	3.586 3.8	50.4 53.5	49.6 46.5

Table 36

Ames Diesel Particulate Data
Baseline

Deutz F6L 714

RPM/ °C	kW	Soluble				Insoluble				Total				% Soluble	% Insoluble
		mg/m^3	g/hr	g/kW. hr	g/kg (fuel)	mg/m^3	g/hr	g/kW. hr	g/kg (fuel)	mg/m^3	g/hr	g/kW. hr	g/kg (fuel)		
2200/ 441°C	78.4	51.21	25.224	0.322	1.226	52.39	25.803	0.329	1.254	103.6	51.027	0.651	2.479	49.4	50.6
	78.4	44.91	21.979	0.28	1.075	46.36	22.688	0.289	1.109	91.26	44.668	0.57	2.184	49.2	50.8
2200/ 340°C	52.5	94.59	48.537	0.925	3.018	54.59	28.014	0.534	1.742	149.18	76.551	1.459	4.761	63.4	36.6
	52.5	70.66	35.876	0.684	2.255	57.33	29.109	0.555	1.830	127.99	64.985	1.238	4.085	55.2	44.8
1900/ 402°C	71.8	32.45	13.507	0.188	0.782	59.2	24.642	0.343	1.427	91.65	38.149	0.532	2.209	35.4	64.6
	71.8	39.22	16.459	0.229	0.945	58.54	24.562	0.342	1.411	97.76	41.021	0.572	2.356	40.1	59.9
1900/ 306°C	48.0	55.57	23.921	0.498	1.807	54.72	23.554	0.491	1.779	110.29	47.476	0.989	3.586	50.4	49.6
	48.0	62.57	27.097	0.564	2.034	54.3	23.517	0.49	1.766	116.87	50.614	1.054	3.8	53.5	46.5

Table 37

Ames Diesel Particulate Data
J. M. Catalyst

Deutz F6L 714

RPM/ °C	kW	Soluble				Insoluble				Total				% Soluble	% Insoluble
		mg/m³	g/hr	g/kW. hr	g/kg (fuel)	mg/m³	g/hr	g/kW. hr	g/kg (fuel)	mg/m³	g/hr	g/kW. hr	g/kg (fuel)		
2200/ 457°C	78.4	20.36	10.074	0.128	0.487	39.13	19.357	0.247	0.936	59.49	29.431	0.375	1.424	34.2	65.8
	78.4	11.66	5.744	0.073	0.279	25.46	12.542	0.16	0.609	37.12	18.286	0.233	0.889	31.4	68.6
2200/ 338°C	52.5	5.25	2.704	0.052	0.168	32.96	16.964	0.323	1.052	38.21	19.669	0.375	1.219	13.8	86.2
	52.5	3.58	1.835	0.035	0.144	25.87	13.256	0.253	0.825	29.45	15.092	0.288	0.940	12.2	87.8
1900/ 420°C	71.8	14.69	6.315	0.088	0.354	30.24	13.002	0.181	0.729	44.93	19.318	0.269	1.083	32.7	67.3
	71.8	6.52	2.787	0.039	0.157	26.78	11.451	0.16	0.645	33.3	14.238	0.198	0.803	19.6	80.4
1900/ 310°C	48.0	11.12	4.793	0.100	0.361	26.26	11.322	0.236	0.854	37.38	16.115	0.336	1.215	29.7	70.3
	48.0	14.11	6.136	0.128	0.459	17.95	7.805	0.163	0.584	32.07	13.94	0.290	1.043	44.0	56.0

TABLE 38

Deutz F6L 714 Engine Conditions
For Baseline and Purifier Tests

Engine Speed rpm	Load kW	Fuel Consumption Rate kg/h	Exhaust Flow Rate m^3/min.	Temperature °C Cylinder 1	2	3	4	5	6	Intake Air	Right Manifold	Left Manifold	Exhaust Back Pressure cm H_2O Right Bank	Left Bank
						Baseline Tests								
2200	105	27.0	7.8							24	582	608	16	4
2200	78	20.7	8.3							24	450	432	10	4
2200	53	16.1	8.4							23	337	343	9	5
1900	96	23.2	6.5							27	567	568	14	11
1900	72	17.2	7.2							23	400	404	9	9
1900	48	13.1	7.3							24	305	307	14	5
1600	82	18.8	5.9							24	519	532	22	-3
						Purifier Tests								
2200	105	26.8	7.8	569	631	585	601	641	587	24	599	548	72	59
2200	78	20.9	8.3	439	487	460	472	511	464	29	475	438	57	48
2200	53	16.0	8.4	326	368	355	352	383	352	28	359	336	53	43
1900	96	23.2	6.5	548	614	560	590	623	581	28	575	526	52	43
1900	72	17.8	7.2	402	452	429	438	472	430	28	437	402	44	35
1900	48	13.4	7.3	292	333	316	316	348	317	27	320	300	43	32
1600	82	18.6	5.9	500	557	511	539	567	537	27	524	483	38	33

Table 39

Gaseous Concentration and Efficiency Summary for a Purifier Equipped Deutz F6L 714

Engine Speed RPM	Load	CO_2 %		O_2 %*		CO ppm			THC ppm**			NO_x ppm			NO ppm			NO_2 ppm		
	kW	Base	Post-Purifier	Base	Post-Purifier	Base	Fost-Purifier	% Reduction	Base	Post-Purifier	% Reduction	Base	Post-Purifier	% Reduction	Base	Post-Purifier	% Reduction	Base	Post-Purifier	% Reduction
2200	105	10.0	11.0	6.8	5.4	380	2	99.5	120	10	91.7	630	547	13.2	626	547	11.8	10	0	100
2200	78	7.2	8.0	10.8	9.7	350	7	98.0	180	14	92.2	681	524	23.1	671	488	27.3	10	36	-260
2200	63	5.5	6.0	13.3	12.6	340	9	97.4	230	15	93.5	630	544	13.7	589	407	30.9	41	137	-234
1900	96	10.2	10.9	6.5	5.6	300	2	99.3	110	12	89.1	549	493	10.2	539	493	8.5	10	0	100
1900	72	6.9	7.7	11.3	10.1	240	8	96.7	150	17	88.7	681	564	17.2	681	442	35.1	0	122	-00
1900	48	5.2	5.6	13.7	13.1	210	7	96.7	160	15	90.6	610	539	11.6	610	437	28.4	0	102	-00
1600	82	9.2	10.2	8.0	6.5	200	2	99.0	120	10	91.7	529	452	14.6	529	447	13.4	0	5	-00

Note: * O_2 Concentrations Extrapolated from Holtz Curve.

** Total Hydrocarbons Expressed as Equivalent Methane (CH_4).

Table 40

Baseline Carbon Monoxide Concentrations and Emission Rates for a Deutz F6L 714

Speed RPM	Load kW	ppm	g/h	g/kW.h	g/kg (fuel)
2200	105	383	208	1.99	7.71
2200	78	353	205	2.61	9.88
2200	53	343	202	3.85	12.58
1900	96	303	139	1.45	5.97
1900	72	242	121	1.69	7.07
1900	48	212	107	2.24	8.22
1600	82	202	83	1.02	4.41

Table 41

Carbon Monoxide Concentrations and Emission Rates for a Purifier Equipped Deutz F6L 714

Speed RPM	Load kW	ppm	g/h	g/kW.h	g/kg (fuel)	% Reduction
2200	105	2	1.1	0.01	0.04	99.5
2200	78	7	4.1	0.05	0.20	98.0
2200	53	9	5.4	0.10	0.33	97.4
1900	96	2	0.9	0.01	0.04	99.3
1900	72	8	4.0	0.06	0.24	96.7
1900	48	7	3.6	0.07	0.27	96.7
1600	82	2	0.8	0.01	0.04	99.0

Table 42

Baseline Total Hydrocarbon Concentrations and Emission Rates for a Deutz F6L 714

Speed RPM	Load kW	ppm	g/h	g/kW.h	g/kg (fuel)
2200	105	120	41.5	0.40	1.53
2200	78	180	64.8	0.83	3.12
2200	53	230	82.8	1.58	5.15
1900	96	110	32.0	0.33	1.38
1900	72	150	46.5	0.65	2.71
1900	48	160	49.5	1.03	3.78
1600	82	120	31.1	0.38	1.65

Note: Total Hydrocarbon Values Expressed as Equivalent Methane (CH_4).

Table 43

Total Hydrocarbon Concentrations and Emission Rates for a Purifier Equipped Deutz F6L 714

Speed RPM	Load kW	ppm	g/hr	g/kW.h	g/kg (fuel)	% Reduction
2200	105	10	3.5	0.03	0.13	91.7
2200	78	14	5.0	0.06	0.24	92.2
2200	53	15	5.4	0.10	0.34	93.5
1900	96	12	3.5	0.04	0.15	89.1
1900	72	17	5.3	0.07	0.31	88.7
1900	48	15	4.6	0.10	0.35	90.6
1600	82	10	2.6	0.03	0.14	91.7

Note: Total Hydrocarbon Values Expressed as Equivalent Methane (CH_4).

Table 44

Baseline Oxides of Nitrogen Concentrations and Emission Rates for a Deutz F6L 714

Engine Speed RPM	Load kW	NO				NO_2				NO_x as NO_2			
		ppm	g/hr	g/kW.hr	g/kg Fuel	ppm	g/hr	g/kW.hr	g/kg Fuel	ppm	g/hr	g/kW.hr	g/kg Fuel
2200	105	620	395	3.78	14.6	10	9.93	0.09	0.37	630	616	5.88	22.8
2200	78	671	445	5.68	21.5	10	10.34	0.13	0.50	681	693	8.84	33.4
2200	53	589	391	7.46	24.3	41	41.38	0.79	2.57	630	641	12.22	39.9
1900	96	539	289	3.02	12.5	10	8.37	0.09	0.36	549	452	4.72	19.5
1900	72	681	389	5.43	22.7	0	0.00	0.00	0.00	681	597	8.32	34.8
1900	48	610	348	7.24	26.6	0	0.00	0.00	0.00	610	533	11.10	40.8
1600	82	529	253	3.09	13.4	0	0.00	0.00	0.00	529	388	4.74	20.6

Table 45

Oxides of Nitrogen Concentrations and Emission Rates for a Purifier Equipped Deutz F6L 714

Engine Speed RPM	Load kW	NO				NO_2				NO_x as NO_2				Percent Reduction		
		ppm	g/h	g/kW.h	g/kg (fuel)	ppm	g/h	g/kW.h	g/kg (fuel)	ppm	g/h	g/kW.h	g/kg (fuel)	NO	NO_2	NO_x as NO_2
2200	105	547	348	3.33	12.9	0	0.0	0.00	0.00	547	534	5.11	19.8	11.8	100	13.2
2200	78	488	324	4.13	15.6	36	36.2	0.46	1.74	524	533	6.79	25.7	27.3	-260	23.1
2200	53	407	270	5.14	16.8	137	140	2.66	8.69	544	553	10.5	34.4	30.9	-234	13.7
1900	96	493	265	2.76	11.4	0	0.0	0.00	0.00	493	406	4.24	17.5	8.5	100	10.2
1900	72	442	253	3.52	14.7	122	107	1.49	6.23	564	494	6.89	28.8	35.1	-∞	17.2
1900	48	437	249	5.19	19.1	102	89	1.85	6.80	539	471	9.81	36.0	28.4	-∞	11.6
1600	82	447	214	2.62	11.4	5	3.73	0.05	0.20	452	332	4.06	17.6	15.5	-∞	14.6

TABLE 47

Sulfur Dioxide and Sulfate Concentration and Emission Rates for a Purifier Equipped Deutz F6L 714

Engine Speed RPM	Load kW	T°C	SO_2				$SO_4^=$			
			ppm	g/hr	g/kW.hr	g/kg Fuel	ppm	g/hr	g/kW.hr	g/kg Fuel
2200	78	457	1.4	1.8	0.02	0.09	12.9	5.7	0.07	0.27
			3.4	4.5	0.06	0.22		45	0.58	2.2
1900	72	420	3.4	4.0	0.06	0.22	15	22	0.30	1.21
			3.5	4.1	0.06	0.23		32	0.44	1.77
2200	53	338	10	13	0.25	0.83	6	7.7	0.15	0.50
			9.2	12	0.22	0.76		14	0.27	0.94
1900	48	310	12	14	0.29	1.1	3.5	5.5	0.12	0.42
			13	16	0.33	1.2		7.3	0.15	0.54

TABLE 47

Sulfur Dioxide and Sulfate Concentration and Emission Rates for a Purifier Equipped Deutz F6L 714

Engine Speed RPM	Load kW	T°C	SO_2				$SO_4^=$			
			ppm	g/hr	g/kW.hr	g/kg Fuel	ppm	g/hr	g/kW.hr	g/kg Fuel
2200	78	457	1.4 3.4	1.8 4.5	0.02 0.06	0.09 0.22	12.9	5.7 45	0.07 0.58	0.27 2.2
1900	72	420	3.4 3.5	4.0 4.1	0.06 0.06	0.22 0.23	15	22 32	0.30 0.44	1.21 1.77
2200	53	338	10 9.2	13 12	0.25 0.22	0.83 0.76	6	7.7 14	0.15 0.27	0.50 0.94
1900	48	310	12 13	14 16	0.29 0.33	1.1 1.2	3.5	5.5 7.3	0.12 0.15	0.42 0.54